Arming the Fleet

THIRD EDITION HIGHLIGHTS

1943 - 2011

Providing Our Warfighters
the Decisive Advantage

Naval Air Warfare Center Weapons Division
China Lake and Point Mugu, California

Naval Air Systems Command

Sailors and Marines Armed with Confidence…

Because we develop, deliver, and sustain aircraft, weapons, and systems—on time, on cost, with proven capability and reliability—so they succeed in every mission and return safely home.

“I cannot think of a prouder statement when asked what our occupation may be than to say ‘I serve the United States of America.’”

—John F. Kennedy, President of the United States

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NAVAIR Overview

The Naval Air Systems Command (NAVAIR) delivers weapon systems to Sailors and Marines for Navy and Marine Corps missions. Products and services include fixed- and rotary-wing aircraft, avionics, air- and surface-launched weapons, electronic warfare (EW) systems, cruise missiles, unmanned aerial vehicles (UAVs), launch and arresting gear, and training systems.

NAVAIR encompasses eight sites across the country. The Aircraft Division has sites at Patuxent River, Maryland; Lakehurst, New Jersey; and Orlando, Florida. NAVAIR depots are located at North Island, California; Jacksonville, Florida; and Cherry Point, North Carolina. The Naval Air Warfare Center Weapons Division (NAWCWD) includes sites at China Lake and Point Mugu, California. The entire NAVAIR organization has made significant contributions to the Fleet by providing total life-cycle support: research, design, development, and engineering; acquisition; test and evaluation (T&E); repair and modification; and in-service engineering and logistics support.

Many NAVAIR publications have documented significant contributions to the Fleet in support of naval aviation and warfighter requirements. This document, produced by NAWCWD, focuses specifically on the weapons and systems research, development, test, and evaluation (RDT&E) contributions made at China Lake and Point Mugu since 1943. During every U.S. military crisis since World War II, RDT&E efforts at China Lake and Point Mugu have played a significant role—developing and testing weapons and systems that work.

NAWCWD Vision, Mission, and Goals

The **NAWCWD Vision** is *to be the leader providing innovative, integrated, and dominant warfighting effects for our naval, joint, and coalition forces*. The **NAWCWD Mission** is *to execute full-spectrum weapons and warfare systems research, development, acquisition, test, and evaluation (RDAT&E)*. The Mission is enabled through recruiting, developing, and retaining a relevant, qualified workforce; developing, maintaining, and operating unique cross-domain land, air, and sea ranges and laboratory capabilities; and partnering with industry, academia, Department of Defense (DoD), and the international community. In the performance of the Mission, stewardship of natural resources and the environment is a paramount duty.

NAWCWD is fully engaged in the execution and support of work across the breadth of RDAT&E. A major goal is to provide naval, joint, and coalition partners with products and services on time and on budget. The Command supports a wide variety of customers and provides substantial resources to continue developing, delivering, and sustaining affordable, quality products and services.

Pursuit of key technology-driven emerging capabilities is another major goal. Technology, innovation, research, and development are the cornerstones that allow NAWCWD to rapidly counter evolving threats with novel warfighter capabilities. Substantial investment and involvement in independent and applied research and core science and technology networks keep NAWCWD at the forefront of relevant technologies and its application to the Mission.

NAWCWD "Firsts"

NAWCWD provides direct Fleet support for naval aviation and is recognized for a number of significant firsts. NAWCWD has extensive experience in developing, perfecting, and testing military components and subsystems that also have direct application to space missions. Although work for other government agencies represents only a very small fraction of the total workload, NAWCWD is occasionally called upon by the National Aeronautics and Space Administration (NASA) to lend expertise to projects of national importance. Lessons learned from joint projects help NAWCWD find solutions to naval aviation problems. China Lake and Point Mugu are recognized for several space-related and earlier undersea firsts.

NAWCWD—Making History

Weapons Firsts…

- Fire-and-forget guided missile under 6 pounds—Spike
- Air-to-air guided missile used in combat—Sidewinder
- Successful anti-radiation missile (ARM)—Shrike
- Air-to-surface precision-guided missile—Walleye
- Fire-and-forget precision-guided imaging infrared (IR) 2.75-inch rocket—Low-Cost Guided Imaging Rocket (LOGIR)
- Low collateral damage precision-guided munition (PGM) warhead, 85% less explosive, same mass properties—Low Collateral Damage Bomb (LCDB, also known as LOCO)
- Feasibility studies, concept development, and early testing—Polaris missile
- Nonnuclear components and testing—atomic bomb
- Plastic-bonded explosives
- U.S. aircraft rockets
- "No-smoke" missiles
- Controlled fragmentation Pearson Notch, still the standard method for warhead case controlled fragmentation
- Metal augmentation charge (MAC) enhanced thermobaric warhead—Hellfire AGM-114N
- U.S. Navy's premier hard target penetration weapon—BLU-116/B
- Cast ductile iron warheads—a family of Mk 80 series weapons
- Cast iron weapon store qualified for flight on Air Force and Navy aircraft
- Heavy-wall practice bomb

Technology Firsts…

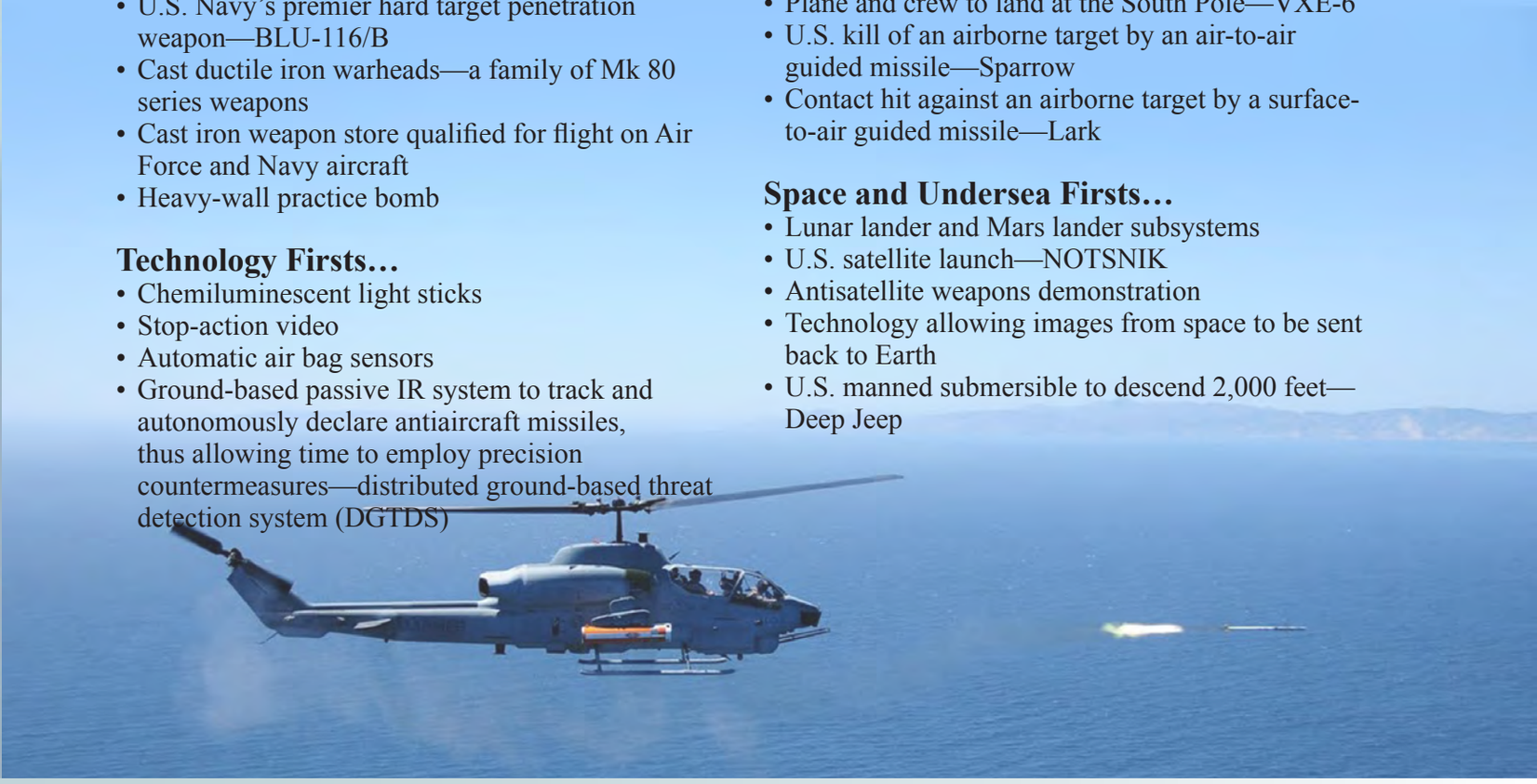
- Chemiluminescent light sticks
- Stop-action video
- Automatic air bag sensors
- Ground-based passive IR system to track and autonomously declare antiaircraft missiles, thus allowing time to employ precision countermeasures—distributed ground-based threat detection system (DGTDS)
- Radar for automatic discrimination of submarine periscopes in high-clutter environments with low probability of false alarms—automatic radar periscope detection and discrimination (ARPDD)
- Reprogrammable self-protection jammer
- Real-time night display of targets
- Real-time X-ray video system to see inside a rocket motor while being fired
- Subject search made by a digital computer
- Body-scanning technology—logarithmic amplifiers
- Active optical and proximity fuze technologies

Testing Firsts…

- Unmanned aircraft to release a Global Positioning System (GPS)-guided weapon
- Pegasus X-47A and Fire Scout RQ-8 UAV flights
- Hellfire missile launch from Sky Warrior UAV
- UAV search and rescue support with Predator B
- Tactical Tomahawk launch with live warhead; first launch from a British submarine
- Standard Missile-3 sea-based ballistic missile intercept
- Standoff Land Attack Missile (SLAM) firing
- Air-to-air "six-on-six" (missiles launched/targets killed)—Phoenix
- Plane and crew to land at the South Pole—VXE-6
- U.S. kill of an airborne target by an air-to-air guided missile—Sparrow
- Contact hit against an airborne target by a surface-to-air guided missile—Lark

Space and Undersea Firsts…

- Lunar lander and Mars lander subsystems
- U.S. satellite launch—NOTSNIK
- Antisatellite weapons demonstration
- Technology allowing images from space to be sent back to Earth
- U.S. manned submersible to descend 2,000 feet—Deep Jeep



NAWCWD, How It All Began

Before China Lake and Point Mugu merged to form NAWCWD, they were separate naval installations, each with its own storied history and reputation.

In the midst of World War II, the Navy established China Lake as the Naval Ordnance Test Station (NOTS) for testing and evaluating rockets being developed by the California Institute of Technology (Caltech). The facility is located 150 miles northeast of Los Angeles in the remote western edge of California's Mojave Desert. The formal mission statement for NOTS in 1943 identified "research, development, and test of weapons" as the Station's primary purpose, which remains its mission today. The first weapons included rockets, such as Mighty Mouse and Zuni, and, because of its remote location, China Lake was also part of the team developing the first atomic weapons.

Also, in 1946, the naval presence at Point Mugu began when Seabees from Port Hueneme put down a Marsden mat runway as the first airstrip in that area. The Navy recognized the importance of a large sea range for T&E functions only 65 miles northwest of Los Angeles, so Point Mugu became the Naval Air Missile Test Center (NAMTC). The NAMTC, which was the U.S. Navy's first instrumented missile test sea range, developed and tested missiles and drones, including the Gorgon, Gargoyle, Lark, and Little Joe.

After World War II, both NOTS and NAMTC excelled in their support of the Warfighter. Scientists and engineers at both locations continued to develop new and innovative weapons. One example is the AIM-9 Sidewinder air-to-air missile, which originated at China Lake and became the world's most used and most copied air-to-air missile.

As the bases added new weapons and technologies to their list of accomplishments, they also continued to evolve as naval installations. For example, in 1958, the Pacific Missile Range (PMR)

at Point Mugu was established. By 1959, NAMTC was renamed the Naval Missile Center (NMC). In 1971, Point Mugu, which was already home to the F-14 Tomcat System Integration Test Station, became host to the Software Support Activity for the Tomcat. Four years later, because the sea ranges were test locations for such weapons as the Harpoon, Tomahawk, Trident, and Standard Missile, the Navy merged the PMR and the NMC into the Pacific Missile Test Center (PMTC). China Lake was also evolving with its warfighter contributions and growing reputation of excellence. By 1967, it was combined with the Naval Ordnance Laboratory at Corona to form the newly created Naval Weapons Center (NWC). In 1979, the National Parachute Test Range at El Centro, California, merged with NWC, further increasing NWC's functionality.

The Navy then continued its efforts to streamline naval functions and consolidate duplicated tasking and research, as well as to broaden the communication between RDT&E facilities. To this end, by 1992, the PMTC, NWC China Lake, and the NAVAIR units at White Sands and Albuquerque, New Mexico, had merged to form NAWCWD. In 2001, the White Sands detachment was transferred to the Naval Sea Systems Command (NAVSEA). NAWCWD is headquartered at China Lake and is a tenant of the Navy Region Southwest, which includes several military bases on the West Coast, such as San Diego; Point Loma; and the Naval Air Station (NAS), Fallon, Nevada.

NAWCWD became one of the largest and most diverse test ranges in the world, with a wide variety of features—mountains, ocean, deep-water ports, protected islands, deserts, canyons, and forests—all close to one another and all highly instrumented. NAWCWD is a billion-dollar-per-year operation, with more than 6,500 employees and 40 major facilities, many of which are not duplicated anywhere else in the world. The installation hosts thousands of official visitors annually, ranging from joint services, allies, and official delegates.

As the Warfighter moves into the future, NAWCWD is leading the way by continuing to develop state-of-the-art weapons and technologies. With its new laboratories and facilities, which will provide new and exciting capabilities, NAWCWD has an exceedingly bright future, will continue to grow significantly, and will remain the U.S. military's leading RDT&E facility far into the future.

China Lake and Point Mugu Designated as Historical Aerospace Sites

For more than 75 years, the American Institute of Aeronautics and Astronautics (AIAA) has been the principal technical society devoted to continuing contributions and global leadership in the aerospace profession. The institute has more than 35,000 members, both professionals and students, and conducts many national technical conferences each year and publishes many textbooks, technical journals, and short courses annually. The AIAA Board of Directors established the historic Aerospace Sites Committee in 1999 to recognize and preserve significant contributions made in both aeronautics and astronautics to culture and technology. Advances and discoveries in the aerospace field have significantly affected the lives of people the world over.

AIAA Point Mugu Historic Aerospace Site

On November 14, 2003, the Naval Base Ventura County at Point Mugu was formally named an AIAA historic site. The citation reads as follows:

> Established in 1946 to provide a comprehensive test and evaluation site for tactical missiles, Point Mugu has been instrumental in the development, test, evaluation, and in-service support of systems including Regulus, Sparrow, Phoenix, Bullpup, Harpoon, SLAM, Tomahawk, Standard, and Rolling Airframe Missile. The first missile launch from an operational submarine was also accomplished at Point Mugu.

The institute designation placed this installation in the company of 20 other historic spots, including Kitty Hawk, North Carolina; Dutch Flats, the San Diego airport where Charles Lindbergh's *Spirit of St. Louis* was tested; the Air Force Flight Test Center at Edwards Air Force Base (AFB), home of legendary test pilots and fledgling astronauts; and the Pasadena plant site where scientists for Aerojet Engineering invented rocket fuel in the 1940s.

AIAA China Lake Historic Aerospace Site

In 2006, China Lake was also chosen an AIAA Historic Aerospace Site, along with the NASA Johnson Space Center, Houston, Texas. The bronze plaque was unveiled by Rear Admiral Walter Skinner at a formal public dedication held at the U.S. Naval Museum of Armament and Technology. The citation reads as follows:

> China Lake is one of the nation's premiere weapons laboratories. Established in 1943, China Lake supports naval aviation and warfighter requirements and will continue to arm the Fleet into the future. The Station conceived and developed rockets during WWII; nonnuclear components for the first atomic bomb; Sidewinder, Shrike, and Walleye missiles; and the Polaris concept. China Lake developed NOTSNIK in 1958 and vital components for the Mars lander in 2004. The Station, a world leader in aircraft–weapons integration, testing, and electronic warfare, developed 75% of the air-launched weapons used during Vietnam and jointly developed 80% of those used during Iraqi Freedom.

As part of the ceremonies, the U.S. Naval Museum of Armament and Technology restored and unveiled two new exhibits, including the Mk IV Fleet version of the Fat Man and the Caleb, the follow-on to NOTSNIK, part of China Lake's early satellite program.

TEAMWORK

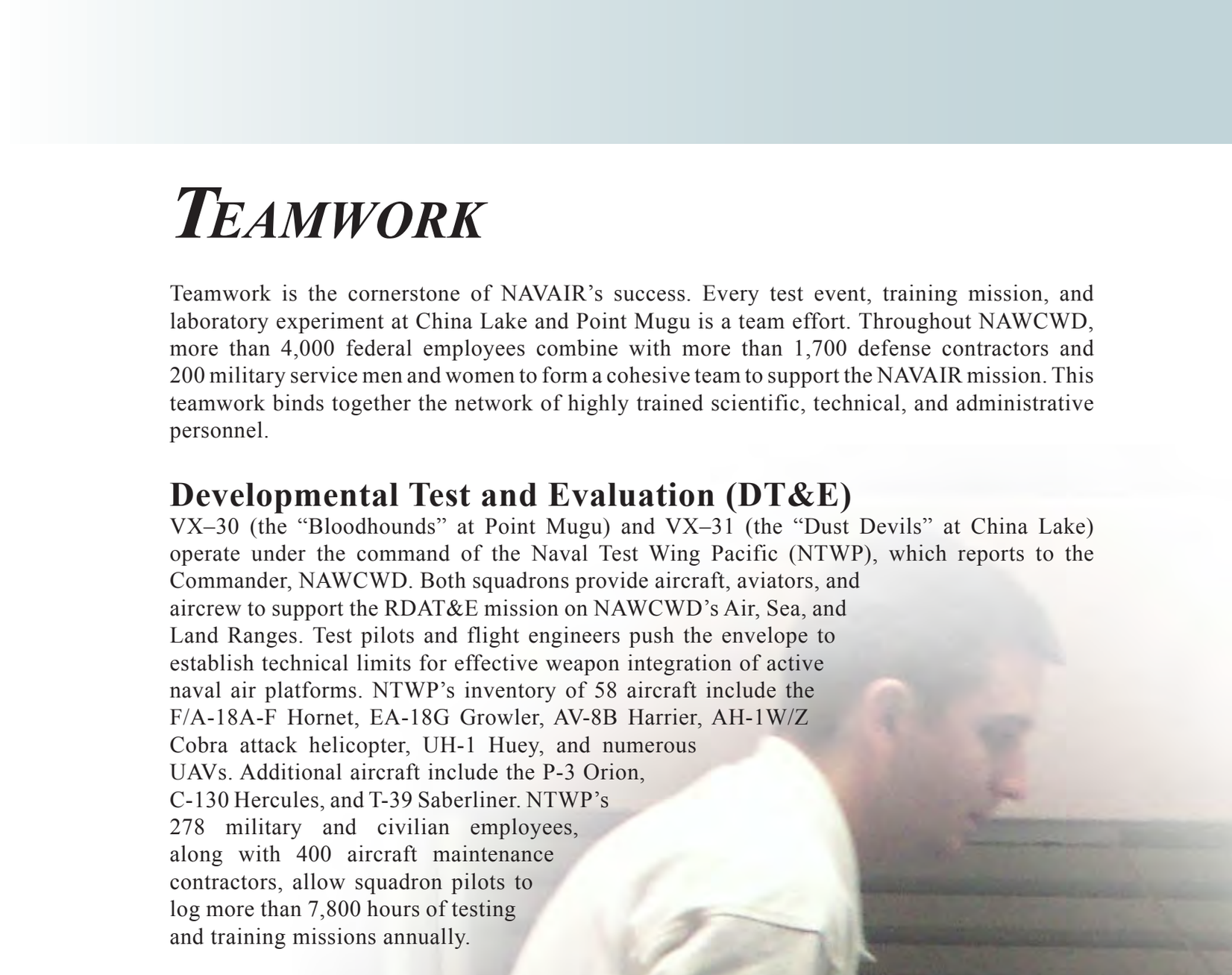
Teamwork is the cornerstone of NAVAIR's success. Every test event, training mission, and laboratory experiment at China Lake and Point Mugu is a team effort. Throughout NAWCWD, more than 4,000 federal employees combine with more than 1,700 defense contractors and 200 military service men and women to form a cohesive team to support the NAVAIR mission. This teamwork binds together the network of highly trained scientific, technical, and administrative personnel.

Developmental Test and Evaluation (DT&E)

VX–30 (the "Bloodhounds" at Point Mugu) and VX–31 (the "Dust Devils" at China Lake) operate under the command of the Naval Test Wing Pacific (NTWP), which reports to the Commander, NAWCWD. Both squadrons provide aircraft, aviators, and aircrew to support the RDAT&E mission on NAWCWD's Air, Sea, and Land Ranges. Test pilots and flight engineers push the envelope to establish technical limits for effective weapon integration of active naval air platforms. NTWP's inventory of 58 aircraft include the F/A-18A-F Hornet, EA-18G Growler, AV-8B Harrier, AH-1W/Z Cobra attack helicopter, UH-1 Huey, and numerous UAVs. Additional aircraft include the P-3 Orion, C-130 Hercules, and T-39 Saberliner. NTWP's 278 military and civilian employees, along with 400 aircraft maintenance contractors, allow squadron pilots to log more than 7,800 hours of testing and training missions annually.

Operational Test and Evaluation (OT&E)

VX-9 (the "Vampires") conducts OT&E of all air-to-ground weapons, air-to-air



weapons, sensors, EW systems, and mission software upgrades to aircraft and weapon systems. More than 350 VX-9 personnel maintain and fly a diverse fleet of approximately 20 aircraft used in the demanding and dynamic role of operational flight test in support of both Navy and Marine Corps tactical aviation. VX-9 currently operates and tests the FA-18E/F Super Hornet, F/A-18A-D Hornet, AV-8B Harrier, EA-18G Growler, and EA-6B, as well as the AH-1W/Z Cobra and UH-1Y helicopters. The squadron logs more than 3,800 flight hours annually and is a tenant of the Naval Air Weapons Station (NAWS) at China Lake.

Marine Aviation Detachment (MAD)

MAD provides project management, aviation support, and technical expertise for assigned Marine Corps weapon systems and subsystems, as well as mission planning at both China Lake and Point Mugu. Although the detachment's headquarters were established in 1987, Marines have been stationed at China Lake since 1943. Today, Marines are actively working on aircraft enhancements to bring new capabilities to the front lines. MAD supports multiple RDT&E missions with VX-31 and OT&E at VX-9. The MAD operates under the command of the Aviation Department, Headquarters, Marine Corps.

Joint Services

Teamwork at NAWCWD is not only internal to the Navy but also reaches across service boundaries to the Marine Corps, Army, Air Force, Coast Guard, and Department of Homeland Security. NAVAIR is at the forefront of joint service activity—joint training, joint testing, joint experimentation, joint research, joint development, and joint acquisition.

China Lake and Point Mugu conduct numerous joint service collaborations, such as the Warfare Response Network and the Homeland Defense Response Team. In addition, the NAWCWD Land Ranges, Sea Range, and Electronic Combat Range (ECR) have hosted virtually every combatant aircraft in the DoD inventory, including Air Force fighters and bombers; Army helicopters; developmental aircraft, such as the F-22 and the F-35; and joint service UAVs.

In addition, Special Operations Forces units have roamed the desert ranges of China Lake, and Marine light armored vehicles have raced across the dry lake beds during live fire exercises. The ranges and laboratories have played principal roles in the United States' largest joint service battle experiments, and Point Mugu was selected as the site of the U.S. Joint Forces Command's (USJFCOM's) Regional Joint National Training Center.

International Services

The United States' international allies benefit from the same principles of teamwork. The first Tomahawk firing from a British submarine, for example, took place on the NAWCWD Sea Range. The Japanese Defense Force conducts annual training and missile development exercises on the Sea Range also. The Italian Air Force trains with the High-Speed Anti-Radiation Missile (HARM) on the NAWCWD Land Ranges; the Royal Danish Navy has participated in Evolved SeaSparrow Missile (ESSM) launches on the ranges as well. Many allied countries send representatives to the F/A-18 Advanced Weapons Laboratory (AWL), where NAWCWD provides its expertise in system integration. Several allies have permanent facilities located on NAWCWD, although their access to the ranges and laboratories is restricted and closely monitored.

Many weapons developed by NAWCWD are later sold to U.S. allies. These foreign military sales (FMS) are contingent on the country being authorized to participate and its ability to provide appropriate funding. To maintain its strategic edge, the DoD may sell a weapon's lower variant without current capabilities, if the military deems the current weapon is essential to U.S. national defense. NAWCWD supports FMS customers by providing range support, weapon integration, and training and technical support.

National and International Forums

NAWCWD has historically played a leadership role in many professional societies. For example, NAWCWD representatives are on the Executive Committee of the Joint Army, Navy, NASA, and Air Force (JANNAF) Interagency Propulsion Committee. Other forum participation includes the following.

- Serves as an active participant in the AIAA.
- Serves on the Missile Sciences Committee and chaired the 2000 Missile Sciences Conference.
- Chairs sessions for the Military Sensor Symposia (MSS) on Active Systems and the MSS national/international conferences.
- Cochairs sessions for the National Fire Control Symposium.
- Serves on the steering committee of the North Atlantic Treaty Organization (NATO) Insensitive Munitions Information Center with representatives from the United Kingdom, Australia, and New Zealand.
- Leads various nationwide and international panels in propulsion, warheads, guidance, control, and fuzing.

Ranges

Overview

NAWCWD's Land and Sea Ranges are unique DoD national assets. With mountains, deserts, canyons, forests, vast ocean, deep water ports, and islands, all close to one another and within restricted airspace, these ranges are used extensively for T&E and training. More than 1,500 test events occur each year. The ranges have hosted virtually every combatant aircraft in the DoD inventory, ranging from Air Force fighters and bombers and Army helicopters to developmental aircraft (e.g., the F-22 and Joint Strike Fighter [JSF] to joint service UAVs). Special Operations Forces units have roamed the desert hills of Superior Valley, and Marine light armored vehicles have raced across the dry flats of Airport Lake during live fire exercises. The ranges have played principal roles in the nation's largest joint service battle experiments. Each year, allied customers, including Australia, Canada, Great Britain, Germany, Switzerland, Italy, and Norway, send hundreds of troops to test weapons and train for conflict. Japan is one of the Sea Range's largest customers.

Ranges are interconnected via a unique Federal Aviation Administration (FAA)-approved restricted corridor (IR-200). Long-range Tomahawk cruise missiles with inert warheads can be launched from the Sea Range to targets on the Land Ranges, so all operational aspects can be tested. In addition, the ranges enjoy great flying weather. Point Mugu has visual meteorological conditions (VMC) 85% of the time and China Lake has VMC 99.5% of the time—in other words, more than 350+ clear days per year.

Land Ranges

The Land Ranges at China Lake represent the Navy's largest single land holding, with 52% of all Navy land worldwide and 85% of the Navy's RDT&E land. The area encompasses 1.1 million acres of land, or 1,700 square miles, and is larger than the state of Rhode Island. The R-2508 restricted airspace encompasses 12% of California's total airspace and is jointly managed by the Navy (China Lake), the Air Force (Edwards AFB), and the Army (Fort Irwin). The ranges support T&E for air and ground conventional weapons, aircraft systems, air-to-air and air-to-surface missiles, rockets, bombs, cluster munitions, cruise missiles, unmanned air vehicles, guns and artillery, fuzes and sensors, mass detonation, training and tactics development, and parachute systems.

Sea Range

The Sea Range at Point Mugu is the largest and most heavily instrumented sea and air range in the United States and encompasses 36,000 square miles of ocean (expandable to 196,000 square miles, from Big Sur south to the United States/Mexico border). The Range Operations Center is capable of monitoring complex full battle group fleet exercises involving aircraft, surface ships, and submarines. San Nicolas Island, 60 miles offshore, is used for littoral warfare training, including theater warfare exercises. San Nicholas Island includes launching facilities and a 10,000-foot-long runway. Point Mugu's targets complex is the only facility to provide full life-cycle support for all Navy aerial and surface targets. The Surface Craft Division at Port Hueneme operates target boats and hulks and provides range surveillance and target recovery. Point Mugu's EW capability is a core area of expertise and supports the electronic attack EA-6B and the new EA-18G stand-off jammer aircraft for the Navy and the Air Force. The latter aircraft is the only dedicated tactical EW platform in the U.S. inventory.

Environmental Stewardship

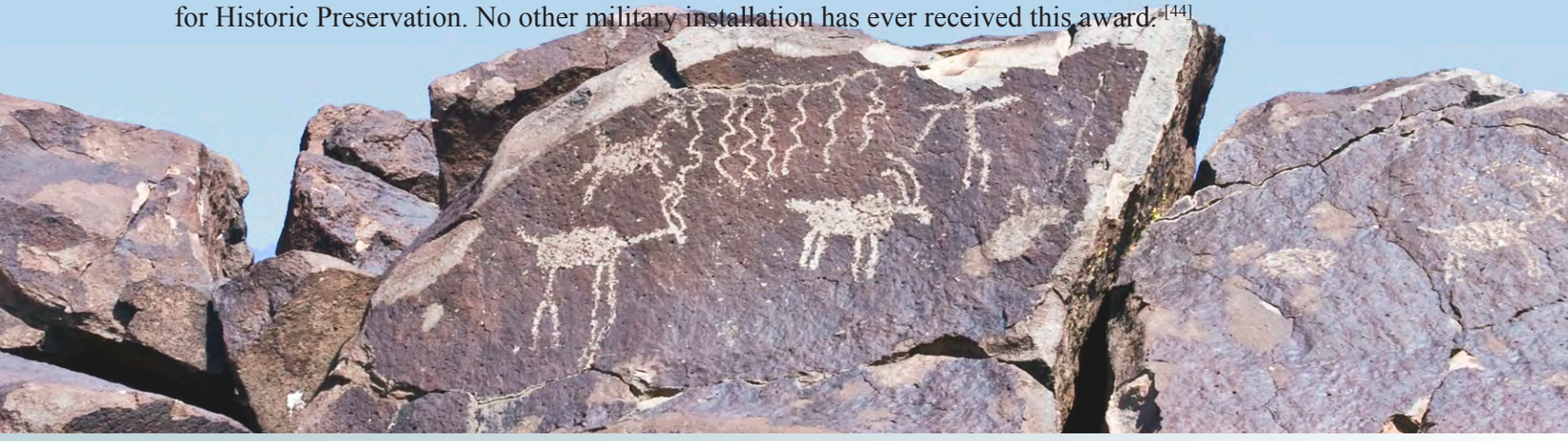
As the reader may recall, the Land Ranges encompass more than 1.1 million acres (larger than the state of Rhode Island) and represent more than a half of the Navy's land worldwide. The vast majority of this land acts as a safety and security buffer and remains in a mostly pristine natural state. To keep it that way, a NAWCWD team of archeologists, ecologists, environmental engineers, and specialists under contract perform long-range environmental resource planning and oversee day-to-day environmental projects. For example, NAWCWD developed management plans for preserving endangered species such as the Mojave ground squirrel, the island night lizard, the desert tortoise, and the San Nicolas Island fox. Policies are also in place to protect birds from aircraft, pinnipeds from missile launches, and wild horses and burros from potential risk on runways. In addition, locations for new facilities and specialized test events are carefully selected to minimize impact, and virtually every mission-related activity is scrutinized to ensure that it complies with environmental laws and regulations. For example, a Final Environmental Assessment and a Finding of No Significant Impact was released in 2008 covering all the new state-of-the-art facilities currently under construction at NAWCWD.

China Lake also protects the valuable desert water sources under its management. To this end, China Lake developed a geographic-information-system-based photographic database for identifying and monitoring its 122 natural water sources.

On San Nicolas Island, isolation has resulted in the evolution of a unique ecosystem. The island is also the largest breeding site in the world for California sea lions. Annually, more than 23,000 elephant seals, 100,000 California sea lions, and 500 harbor seals use the island's beaches. To protect that ecosystem, NAWCWD constructed a moveable open-ocean supply pier. This one-of-a-kind pier allows cargo to be transported to and from San Nicolas Island with the least amount of impact on that delicate environment.

Cultural Stewardship

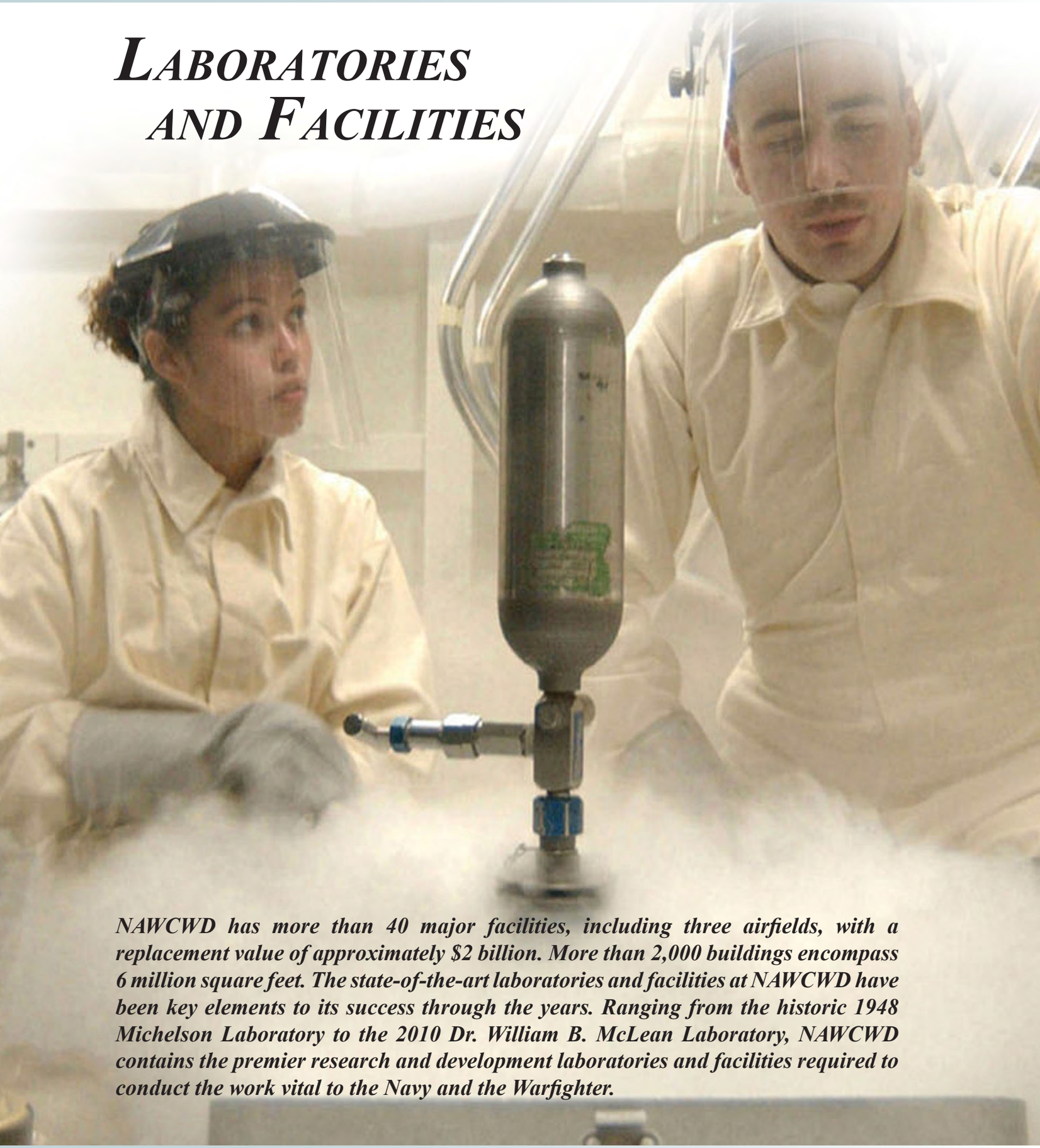
In another effort to manage and protect its land, NAWCWD conducts cultural resource inventories to identify archaeological, historical, and traditional properties. To date, inventories have been completed on roughly 11,000 acres. One such property is a 100-square-mile collection of ancient rock art. This collection is the largest concentration of rock art in the world and is a National Registered Historic Landmark. In recognition for preserving this unique site, NAWCWD received the Governor's Award for Historic Preservation. No other military installation has ever received this award.[44]



“The China Lake range was selected because of the vast flying space, specific simulators, and technical capabilities. We are grateful to this community. They have accepted us in a very warm way. We are flying our Tornados with the HARM at the ECR. Everyone knows that China Lake is the home of the HARM. China Lake, in my opinion, is the most unique range in the world for testing weapon systems.”

—Colonel Pino Scancarello of the Italian Air Force staff

Laboratories and Facilities



NAWCWD has more than 40 major facilities, including three airfields, with a replacement value of approximately $2 billion. More than 2,000 buildings encompass 6 million square feet. The state-of-the-art laboratories and facilities at NAWCWD have been key elements to its success through the years. Ranging from the historic 1948 Michelson Laboratory to the 2010 Dr. William B. McLean Laboratory, NAWCWD contains the premier research and development laboratories and facilities required to conduct the work vital to the Navy and the Warfighter.

Laboratories and Facilities

Advanced Weapons Laboratory (AWL)

The F/A-18 AWL provides mission system engineering support for all variants of the F/A-18, coordinating all system upgrades and providing system engineering for F/A-18 hardware and software. In addition, the F/A-18 AWL develops its own integration and simulation laboratories, test equipment, and flight instrumentation.

Chemistry Laboratories

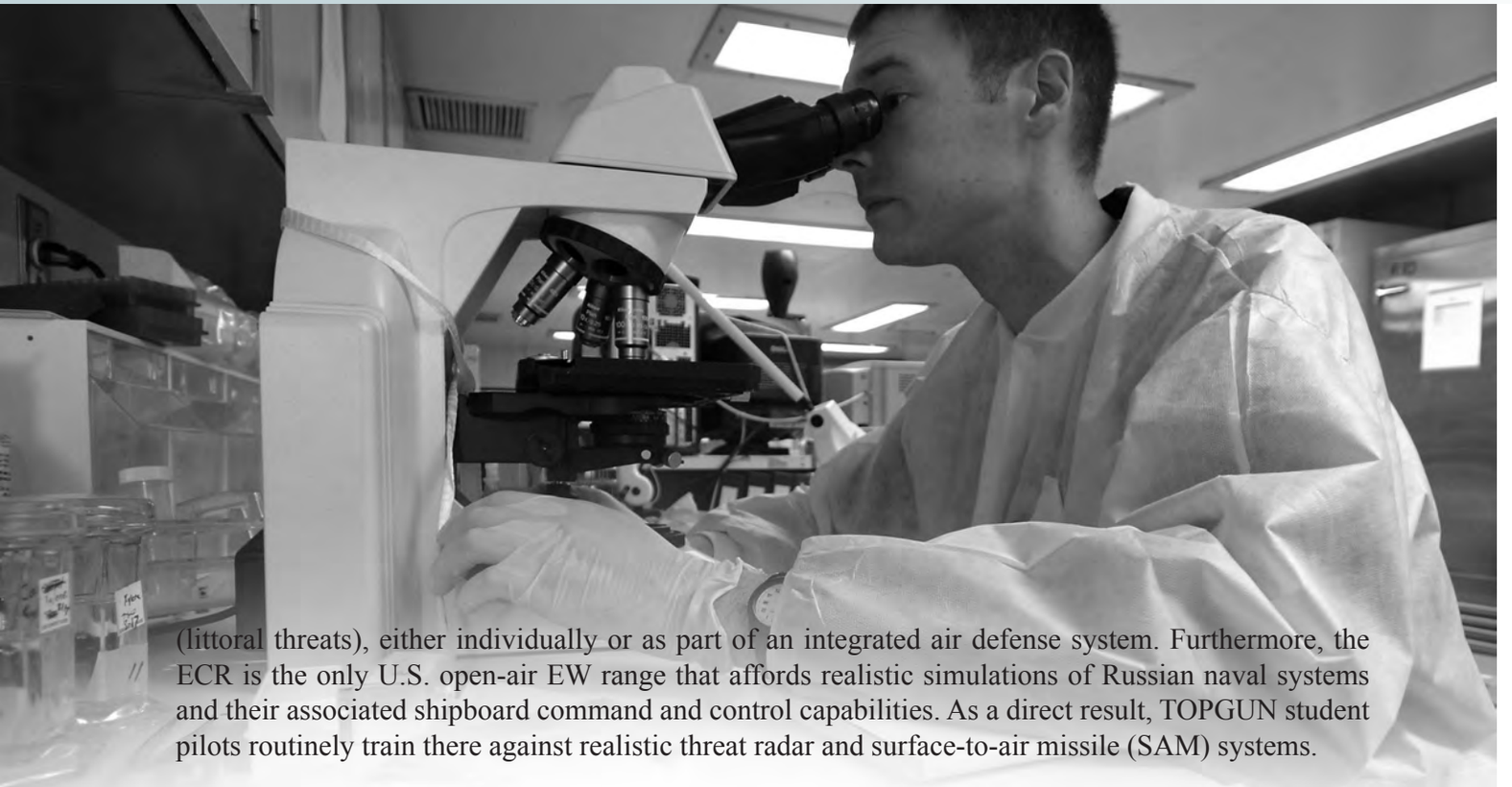
NAWCWD maintains a state-of-the-art research facility staffed with highly trained scientists who clearly understand military-specific technology and Navy needs. Laboratory personnel routinely conduct efforts requiring a rapid response. One example of the facility's many unique capabilities is the High Target Utilization System, which can deposit uniform optical coatings at high rates over much larger areas than standard systems. Facilities include a large well-equipped clean room, which can be utilized for micro/nanofabrication. In the synthetic chemistry laboratories, the synthesis, formulation, and characterization of energetic materials are performed. A few notable examples of important developments stemming from work within these laboratories include hexanitrohexaazaisowurtzitane (CL-20), the most powerful explosive known to date and a formulation that represents a giant leap in the field of energetic materials; space-survivable materials, which have been tested with great success on the International Space Station; and biofuels that are derived from butanol and pinenes that show great promise as renewable high-performing fuels.

Dr. William B. McLean Laboratory

Dedicated to the founder of the Sidewinder missile, the Dr. William B. McLean Laboratory at China Lake is a 177,000-square-foot laboratory that provides more than 50,000 square feet for general engineering, modeling and simulation (M&S), and logistics. Furthermore, this complex, which can accommodate more than 500 people, houses facilities for conferences and symposia.

Electronic Combat Range (ECR)

The ECR is the Navy's principal open-air range for the T&E of airborne electronic combat systems. Facilities provide a realistic electronic combat environment, including threat systems and operation and range control capabilities, as well as instrumentation to obtain time, space, position information (TSPI) and telemetry, optical, and communication data. Other resources include data processing and display, signal monitoring, and calibration systems, as well as assessment and repair facilities for use by T&E and training customers. This complex is the only U.S. DoD ECR having the necessary infrastructure for testing against naval air defense systems and combinations of land and naval systems



(littoral threats), either individually or as part of an integrated air defense system. Furthermore, the ECR is the only U.S. open-air EW range that affords realistic simulations of Russian naval systems and their associated shipboard command and control capabilities. As a direct result, TOPGUN student pilots routinely train there against realistic threat radar and surface-to-air missile (SAM) systems.

Fire Sciences Laboratory (FSL)

The FSL conducts small- and large-scale fire testing in support of shipboard aviation fire protection, weapons protection, and Navy and Marine Corps shore-based fire protection. The laboratory consists of two primary facilities, the FSL Burn Room and the Carrier Deck Firefighting Test Facility (Mini Deck). The FSL is the only Navy test facility that provides both small-scale testing in controlled weather conditions and full-scale fire testing on site with jet fuel and full flight deck conflagration environmental conditions. These include mass fuel spill, complete hose station capability, wind generation, full-scale weapons and aircraft simulation, and a P-25 firefighting vehicle.

Fuze Test Facility

The Fuze Test Facility at the China Lake Propulsion Laboratories (CLPL) is a new 15,000-square-foot renovation of two existing explosive docks. The facility, operational in fiscal year 2011, provides laboratory space for performing fuze ordnance assessments.

Hardware-in-the-Loop (HWIL) Facility

The HWIL Facility at China Lake is a new 17,000-square-foot state-of-the-art facility that contains two large radio frequency (RF)-shielded anechoic chambers. This facility also provides supporting laboratories for the ESSM and Advanced Medium-Range Air-to-Air Missile (AMRAAM) Programs.

In-Service Engineering Laboratory

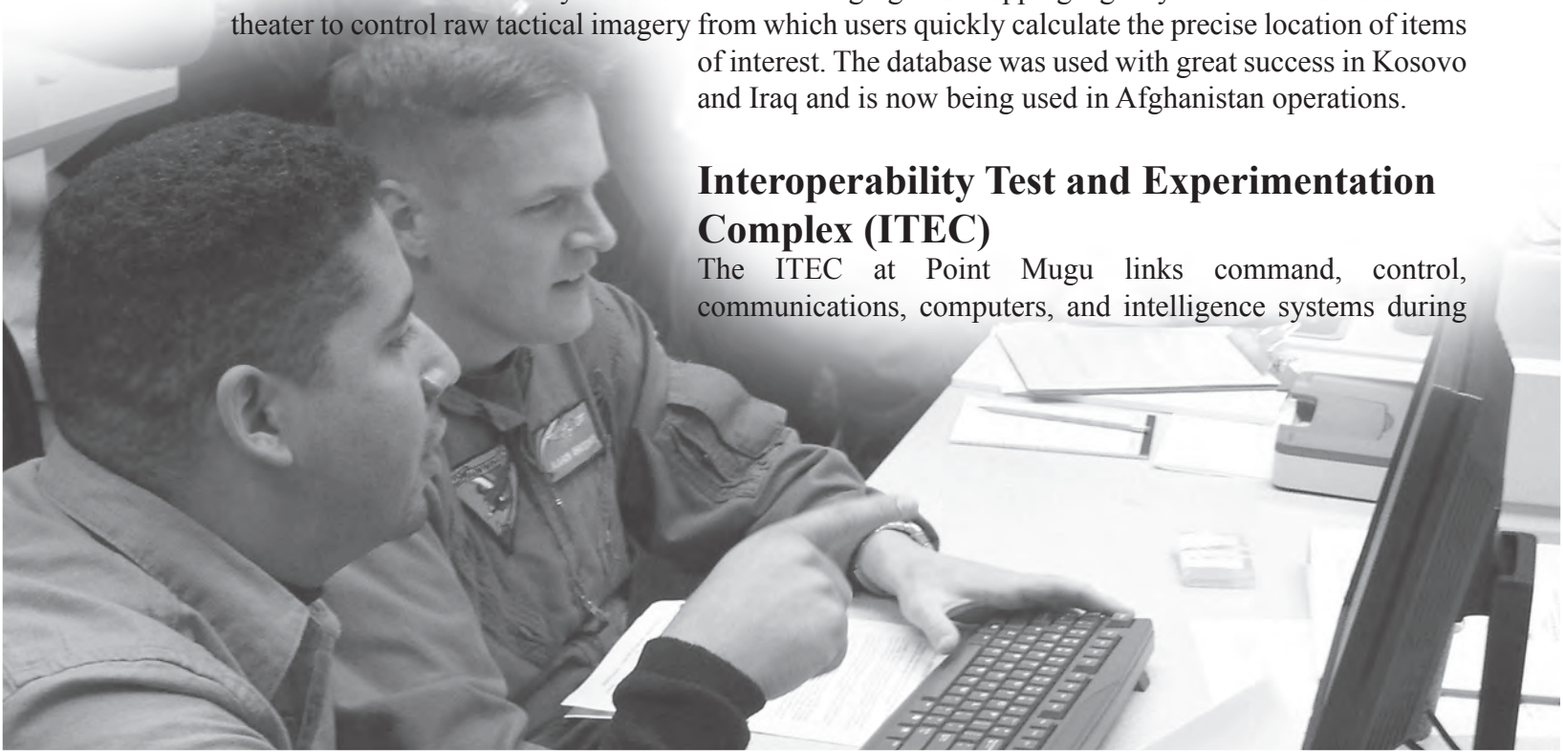
The In-Service Engineering Laboratory at China Lake is a new 20,000-square-foot laboratory that provides support for in-service engineering sustainment and maintenance with functions from other activities.

Insensitive Munitions (IM) Facilities

The IM facilities at China Lake provide a secure and safe environment for destructive tests of weapon systems. These tests evaluate munitions reactions from ambient to hot temperatures, extreme immediate hot temperature, rough handling, and hostile environment impacts. Facilities are secure and free from encroachment and frequently provide data for Army and Air Force testing to evaluate and provide safety margin data prior to full-scale manufacturing approval. In explosives tests conducted at the facility's research and development areas, more than 100 tons of ammunition has been detonated to simulate ammunition ship or magazine accidents.

Integrated Battlespace Arena (IBAR)

The IBAR is an advanced simulation facility. Nine interconnected laboratories and facilities provide simulation and analysis—from the subcomponent to theater levels—with a degree of fidelity, flexibility, and dependability unparalleled in the DoD. Facilities are linked worldwide with multiple fiber-optic networks, including the Secure Internet Protocol Router Network (SIPRNET) and Defense Research and Engineering Network (DREN). In addition, the complex offers extensive range microwave telecommunication capabilities. The Virtual Prototyping Facility has the Navy's first cockpit simulation that includes communications to and from the simulated aircraft to the weapons! If live assets are not available, the IBAR can simulate any aircraft, weapon, target, or terrain. Information is networked or data linked through communication systems from any ground, air, or sea platform. The Precision Engagement Center provides effective targeting and engagement capabilities so that the U.S. military and allied forces can model and rehearse tactical operations and fire integration. In the ongoing War on Terror, IBAR contributes significantly in countering radio-controlled improvised explosive devices (IEDs), EW systems, and unmanned systems (UxS). IBAR engineers and analysts developed a geo-referenced database to register and correlate tactical imagery terrain models based on a database maintained by the U.S. National Imaging and Mapping Agency. The database is used in theater to control raw tactical imagery from which users quickly calculate the precise location of items of interest. The database was used with great success in Kosovo and Iraq and is now being used in Afghanistan operations.



Interoperability Test and Experimentation Complex (ITEC)

The ITEC at Point Mugu links command, control, communications, computers, and intelligence systems during

live fire and simulated test events in a controlled, closely monitored range environment. By linking test, training, experimentation, and evaluation assets with live- and synthetic-exercise resources, the ITEC provides a meeting place for the laboratory and warfighters, thereby enabling a flexible mix of laboratory control and operation dynamics. The ITEC is one of only a few facilities within the DoD that offers a land-based Link-16 capability in a littoral setting.

Joint Counter IED Facility (JCIF)

The JCIF is a specialized facility dedicated entirely to the RDT&E of anti-IED tactics and technologies. It is employed exclusively to produce and deliver "actionable" information pertaining to the performance and compatibility characteristics of counter remote-controlled-IED electronic warfare systems. Terrorism has created its own specialized arsenal of handmade, or improvised, bombs. These devices, often crude in nature, are very inexpensive to build and very deadly to our warfighters. During Operation Iraqi Freedom, these bombs have been the primary cause of United States casualties. In 2005, the Secretary of Defense directed the establishment of the Joint Improvised Explosive Device Defeat Organization (JIEDDO), which then directed China Lake to begin developing the JCIF. The Counter Improvised Explosive Device (CIED) Technical Project Office (TPO) provides daily updates and engineering analysis to fielded forces globally. Information turnaround is as short as 12 hours. The majority of testing is in direct support of requests for information that are generated in theater and prioritized by Combatant Commanders.

Junction Ranch

Junction Ranch provides radar cross section (RCS), microwave measurement, and supporting functions to the Warfighter. This facility maintains a small efficient workforce who works closely with customers; active testing participation is invited and encouraged. Multiple test capabilities are available in one location. Data turnaround is quick, and the facility is capable of supporting competing contractors. Junction Ranch is unique because of its location and radar capability. Due to its remote secure location, there is a minimum level of spurious electromagnetic interference, thus ensuring the highest data quality possible. Surrounded by mountains, the 65-square-mile range and facilities provide precision outdoor RCS measurements of models and real targets, including air, ground, and sea vehicles; very low observables (VLOs); ship models and components; missiles; tactical ballistic missiles; reentry vehicles; ground vehicles; and plumes. The facility is also used to measure antenna patterns and to develop state-of-the-art capabilities in radar, software, and VLO target support functions. This facility can accommodate all levels of security classifications, and environmental clearances are in place to meet customer needs.

Kenneth I. Lichti Range Operations Center

The Kenneth I. Lichti Range Operations Center, located at Point Mugu, is a joint range operations complex built in 2004. This 11.5-million-dollar project includes a 30,000-square-foot multistory structure to house Sea Range test planning, scheduling, and critical data collection functions and equipment, as well as operational synthesis instrumentation and software for interconnectivity of weapons development, test, and evaluation. Also located therein are flight termination systems that can take control of the test articles and then destroy them if they go outside a predetermined envelope. The new warfare concept capabilities of the range center link laboratories and test ranges worldwide to evaluate and improve missiles and weapons for real and simulated battlefield threats. Adjacent to the 36,000-square-mile Point Mugu Sea Range, this addition offers military branches of the DoD and allied forces a multitude of large-scale training involving air-to-air, air-to-surface, surface-to-surface, and surface-to-air exercises.

Laguna Peak Complex

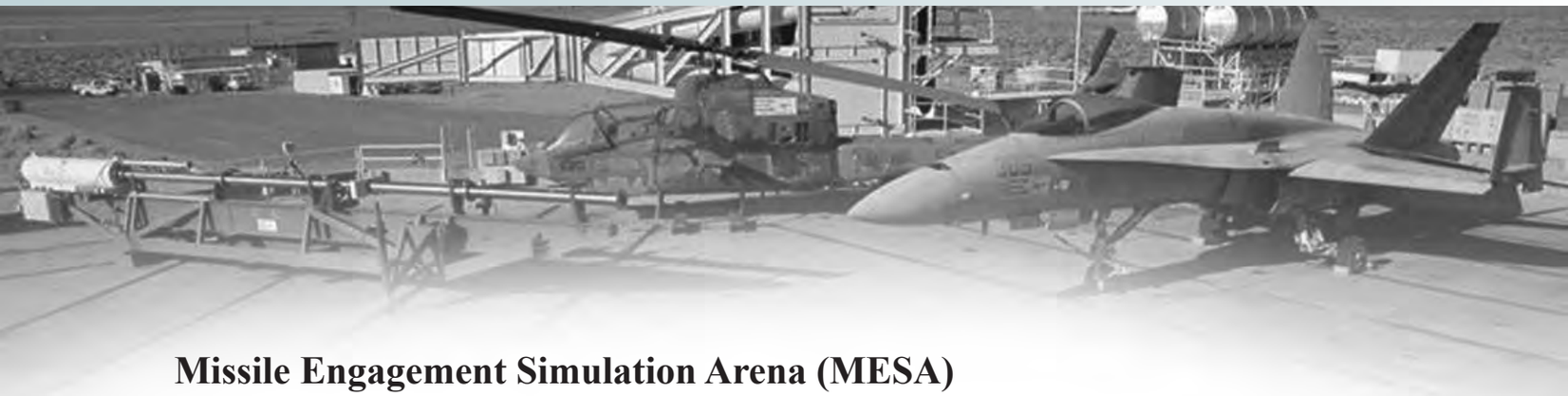
The Laguna Peak Complex at Point Mugu is located on a 1,500-foot-high mountain and provides an elevated line-of-sight location for overlapping coverage of the Sea Range. The facility provides optics coverage, telemetry, airborne and surface target control, radio communication and data transmission, surveillance radar, and a command transmitter system (CTS) for command destruct. Laguna Peak is also a primary site for range safety CTS for all ballistic missile launches from Vandenberg AFB.

Lauritsen Laboratory

The Lauritsen Laboratory at China Lake is primarily devoted to engineering and research activities, including constructing a direct current plasma jet reactor for diamond deposition. This device produces diamond film, which researchers are developing to grow on metals to create diamond-coated ball bearings and other long-wearing, low-friction applications.

Michelson Laboratory

Michelson Laboratory, which was built in the late 1940s, is one of the primary research complexes at China Lake. This premier facility provides 9.5 acres of floor space and houses an astounding array of talented technicians, engineers, scientists, and program managers with specialized knowledge, talents, and expertise. The laboratory is equipped to support basic and applied research in physics, chemistry, aerophysics, metallurgy, and ballistics, as well as development work in propulsion, fire-control, and guidance systems for rockets. This one-of-a-kind resource provides the infrastructure and intellectual capital to advance the state of the art in RDT&E. During its 60-year history, countless weapons were developed within its walls, including Sidewinder, Spike, and Tactical Tomahawk.



Missile Engagement Simulation Arena (MESA)

The MESA measures the electromagnetic interaction of a sensory system (fuze or guidance) with its intended target. It provides cost-effective, timely, and accurate dynamic missile engagement test data. Missile fuzes are tested against various targets, including full-scale fighter aircraft, in a secure, controlled laboratory environment with all-weather, around-the-clock operational capabilities. It is the only facility of its kind that provides a cost-effective and accurate method of developing, testing, and assessing the performance of proximity fuze systems; validating fuze models and endgame simulations; studying the survivability of platforms; and making live fire test and evaluation (LFT&E) predictions. The ability to model encounters with threat targets under realistic and varied conditions and under laboratory conditions sets this facility apart from outdoor backscatter ranges.

Optics and Laser Research Facility

The Optics and Laser Research Facility is located in Lauritsen Laboratory at China Lake. Within this valuable resource, personnel conduct RDT&E on optical materials, components, subsystems, and laser systems. The facility provides cost and time savings to projects because of the rapid prototype fabrication capability. One example is the production of the 16-inch IR range telescopes that were fabricated at less than half the cost of the commercial estimates, with the first prototypes delivered within only 3 months.

Ordnance and Propulsion Laboratories

The Ordnance and Propulsion Laboratories at China Lake represent the Navy's most comprehensive and truly unique center for research and development of missile propulsion, ordnance, and fuzing. This complex provides a one-stop shop for propulsion and ordnance efforts, including the synthesis of ingredients for propellant and explosives for incorporation into weapon systems, as well as the design of warheads, bombs, fuzes, and rocket motors.

Radar Reflectivity Laboratory (RRL)

The RRL, located at Point Mugu, has three indoor anechoic chambers designed for both near- and far-field monostatic and vertical- and horizontal-plane bistatic RCS measurements at frequencies from very high to millimeter waves. These anechoic chambers provide a test facility designed to minimize the reflections from the interior walls, ceiling, and floor to provide equivalent free-space conditions for performing pristine measurements. Pertinent testing includes far-field RCS; monostatic and bistatic RCS measurements of full-size missiles, targets, and components; and scale-model aircraft and ships for survivability analyses, weapons system flight tests, production/quality assurance testing, diagnostic testing, and the development of scattering models.

Radiographic Inspection Facilities (RIFs)

The RIFs conduct baseline inspections to determine conformance, quality, anomalies, and failure analysis in the inspection of very large ordnance items. X-ray testing is conducted and documentation is prepared regarding the internal configuration of existing and prototype ordnance and non-ordnance items. Frequently referred to as "the world's largest X-ray," the high energy computed tomography inspection system, with digital imaging capability, is used to X-ray systems measuring up to 86 inches in diameter and 27 feet in length and weighing up to 130,000 pounds. It is one of only four highly specialized machines in the United States capable of X-raying the largest submarine-launched ballistic missiles (SLBMs) in the Navy's inventory. In addition, the conventional X-ray facility operates the only operational Betatron 23-million-electron-volt magnetic inductance accelerator in the United States. The RIFs support inspections associated with static firings of rocket motors and large bombs and provide a means to conduct diagnostic inspections. This facility is invaluable in providing quality assurance testing for the various large bomb systems deployed to Iraq and Afghanistan. The Tomahawk and weapons from various missile intercept programs for Navy and Air Force Programs are regularly tested here. The RIFs are also utilized to evaluate the new Massive Ordnance Penetrator bomb.

Skytop Propulsion Complex

Skytop provides the infrastructure to conduct static test firings of solid-propellant rocket engines, gas generators, and ignition systems, both fielded and developmental. Evaluations at Skytop include those for rocket motors being qualified for future use in complete weapon systems. Also performed there are aging and surveillance studies to ensure that deployed motors are maintaining specific design capabilities. The multidisciplinary technical team at Skytop is highly trained. Full-scale all-up-round motor experimentation is conducted on weapon systems with up to 2 million pounds of thrust and as large as 92 inches in diameter. Developmental and production acceptance tests, as well as aging motor studies of the Navy's submarine-launched Fleet ballistic missiles, have been performed at Skytop, thus ensuring that the United States has the most reliable strategic deterrent system in existence. Skytop has been instrumental in the developmental testing of most tactical air- and surface-launched weapons currently in use by the Fleet.

Supersonic Naval Ordnance Research Track (SNORT)

The SNORT is a 4-mile-long dual-rail precision-alignment track for the testing of rockets, guided missiles, model and full-scale aircraft, and components under free-flight conditions at velocities from subsonic through supersonic. The SNORT is the second longest and fastest supersonic sled track in the world. In fact, items being tested on the track can reach speeds up to 6,000 feet per second. Testing is extremely cost-effective because SNORT combines many advantages of laboratory testing with

dynamic free-flight testing and allows test article recovery. Tests performed thereon include long-duration runs and controlled deceleration, aircrew safety, terminal ballistics, rain erosion, vehicle and barrier, aeroballistics, damage and destruction, and soft recovery assessments. Complex multiple target penetration tests using live high-explosive-filled warheads are also conducted. Recently, the cleared target areas at the end of and surrounding the track have been used for IED detection testing. The cleared areas offer a secure, controlled environment to test ground- and airborne-detection and disposal methods.

Thompson Laboratory

The Thompson Laboratory at China Lake was named after China Lake's first civilian Technical Director, Dr. L.T.E. Thompson. Thompson Laboratory is primarily devoted to engineering and research activities, such as developing HARM's Block 3A missile guidance software.

Weapons and Armaments Technology Laboratory

The Weapons and Armaments Technology Laboratory is a new facility at China Lake that opened in 2011. This complex is a 75,000-square-foot facility that contains high-bay and small-bay laboratories to support equipment functions. The laboratory provides logistics weapon support capabilities.

Weapons Dynamic RDT&E Center

The Weapons Dynamic RDT&E Center, a new facility at China Lake, provides dynamic testing of all Navy weapon systems, ranging from all-up rounds to components in all life-cycle configurations. This 7,200-square-foot facility provides vibration testing for transportation, shock, shipboard, and aircraft.

Weapons Survivability Laboratory (WSL)

The WSL is the Navy's field activity for weapon system nonnuclear survivability, weapons lethality, and LFT&E assessments. Therein, survivability testing is conducted for all three major services. The WSL is the largest LFT&E facility in the world, encompassing five major test sites capable of supporting full-scale test articles. This complex also includes an underground site to evaluate smaller-scale articles. It is the only facility with three High-Velocity Airflow Systems (HIVASs) generating flight-representative airflow to operating aircraft. The Missile Engagement Threat Simulator is a high-pressure gas gun capable of precisely delivering "live" man-portable air-defense systems (MANPADS) and other projectiles at high velocities. The threat of one person toting an inexpensive IR-guided shoulder-launched missile and successfully destroying a military aircraft is real! For example, during Desert Storm, several F/A-18 and A-10 aircraft incurred major structural damage from SAMs but, fortunately, managed to return safely to base. In addition, during Operation Iraqi Freedom, when Afghan forces attacked al-Qaeda and Taliban holdouts in one of the biggest battles of the War in Afghanistan, seven Apache helicopters were attacked. However, the aircraft had been redesigned based on WSL LFT&E findings; and, although they were hit, all seven managed to fly home.

Weapons Systems Center for Integration (WSCI)

The WSCI, a China Lake facility that opened in 2010, provides a focal point for weapon development and testing, including weapon M&S, mission-level engineering, and integration. The facility contains four secure laboratories within more than 10,000 square feet of laboratory space.

Weapons Systems Support Activities (WSSAs)

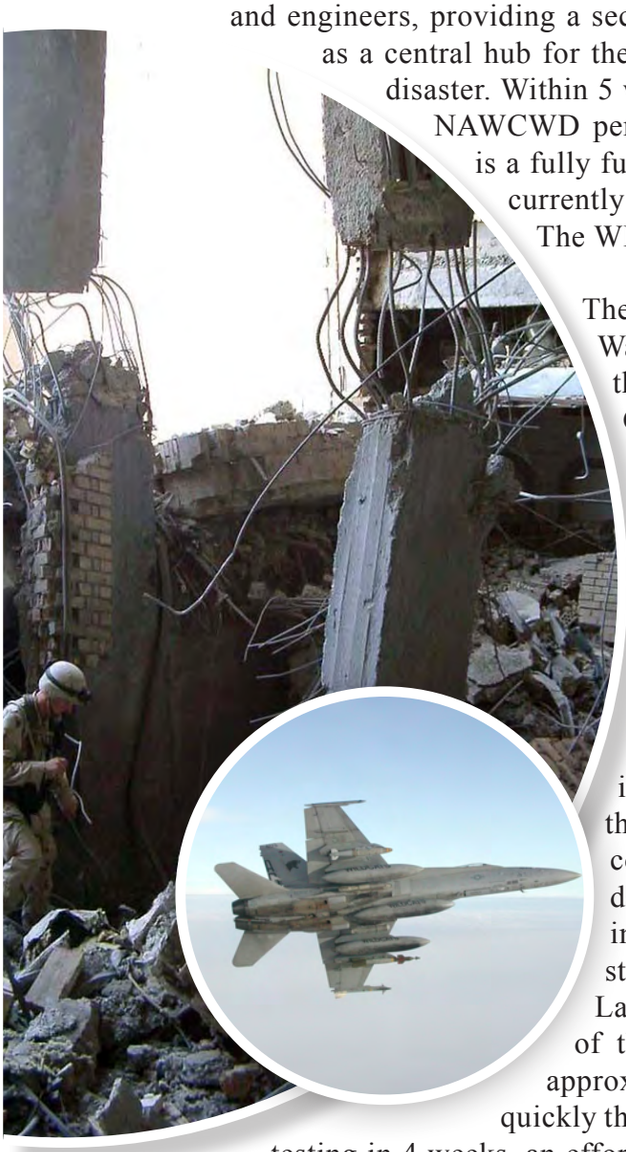
The WSSAs at China Lake afford weapon system support. The WSSA facilities offer a fully controllable environment for executing regression tests and problem investigations. The facility is the only DoD facility that possesses a software development capability, as well as weapon system integration, for the F-14 aircraft. The WSSAs provide periodic functional upgrades due to changing threats, roles, and missions, as well as to correct latent defects or to replace obsolete parts.

War on Terror

NAWCWD supports the War on Terror in many ways; however, the following section is concerned only with direct support for Operation Iraqi Freedom and Operation Enduring Freedom. These two conflicts represent the main thrust of a global effort to curtail and ultimately defeat terrorist cells throughout the world.

War on Terror

After the terrorist attacks of September 11, 2001, China Lake set up the Warfighter Response Center (WRC), with three prime directives: maintaining constant connection between warfighters and engineers, providing a secure state-of-the-art meeting place for that team, and functioning as a central hub for the NAWS commanding officer in the event of a mishap or natural disaster. Within 5 weeks, an open-storage secret site was created, thereby providing NAWCWD personnel and the Warfighter around-the-clock support. The WRC is a fully functional Naval Aviation Weapons Distance Support Center and is currently the NAVAIR aviation help desk for the Naval Aviation Enterprise. The WRC fields more than 500 support requests annually.



The Joint Direct Attack Munition (JDAM) quickly became the Warfighter's weapon of choice during the War on Terror, so much so that supply could not always keep up with demand. To fill this gap, China Lake, in only 3 weeks, provided the necessary maintenance to 630 JDAM tail kits needed by deployed Marine Corps forces. In another effort to get JDAMs to the Fleet, Point Mugu was tasked to provide JDAM capability to legacy F-14Bs, and a crew from the F-14A/B/D integrated product team (IPT) was sent aboard USS *Theodore Roosevelt*, USS *Abraham Lincoln*, and USS *Constellation* to provide the same capability to the F-14D.

The LCDB and the MAC warhead were two China Lake quick-response efforts to provide the Warfighter with increased capability in urban environments. In both cases, the Fleet needed weapons they could employ in urban environments without unnecessary collateral damage. The LCDB, a laser-guided bomb (LGB) developed by China Lake in under 16 months, can engage enemies in semi-hardened structures, with minimal damage to surrounding structures or noncombatants. For their work on the LCDB, China Lake personnel were awarded the Top Navy Scientist and Engineers of the Year Award in 2007. With development and testing taking approximately 13 months, the MAC warhead was fielded even more quickly than the LCDB. VX-9 played a crucial role in that effort by finishing testing in 4 weeks, an effort that normally takes 4 months. The MAC warhead "can take out the first floor of a building without damaging the floors above," thereby making it a valuable asset in the War on Terror.

NAWCWD also provided critical support to the Warfighter's targeting ability with systems like Digital Precision Strike Suite (DPSS), Precision Strike Suite–Special Operations Forces (PSS-SOF), Rapid Attack Information Dissemination and Execution Relay (RAIDER), and the Shared Reconnaissance Pod (SHARP). In the battle of Fallujah, DPSS improved the accuracy and timeliness of targeting capability, while reducing the chances of collateral damage. The WRC at China Lake manages deployment of DPSS and other NAVAIR prototype systems. Like DPSS,

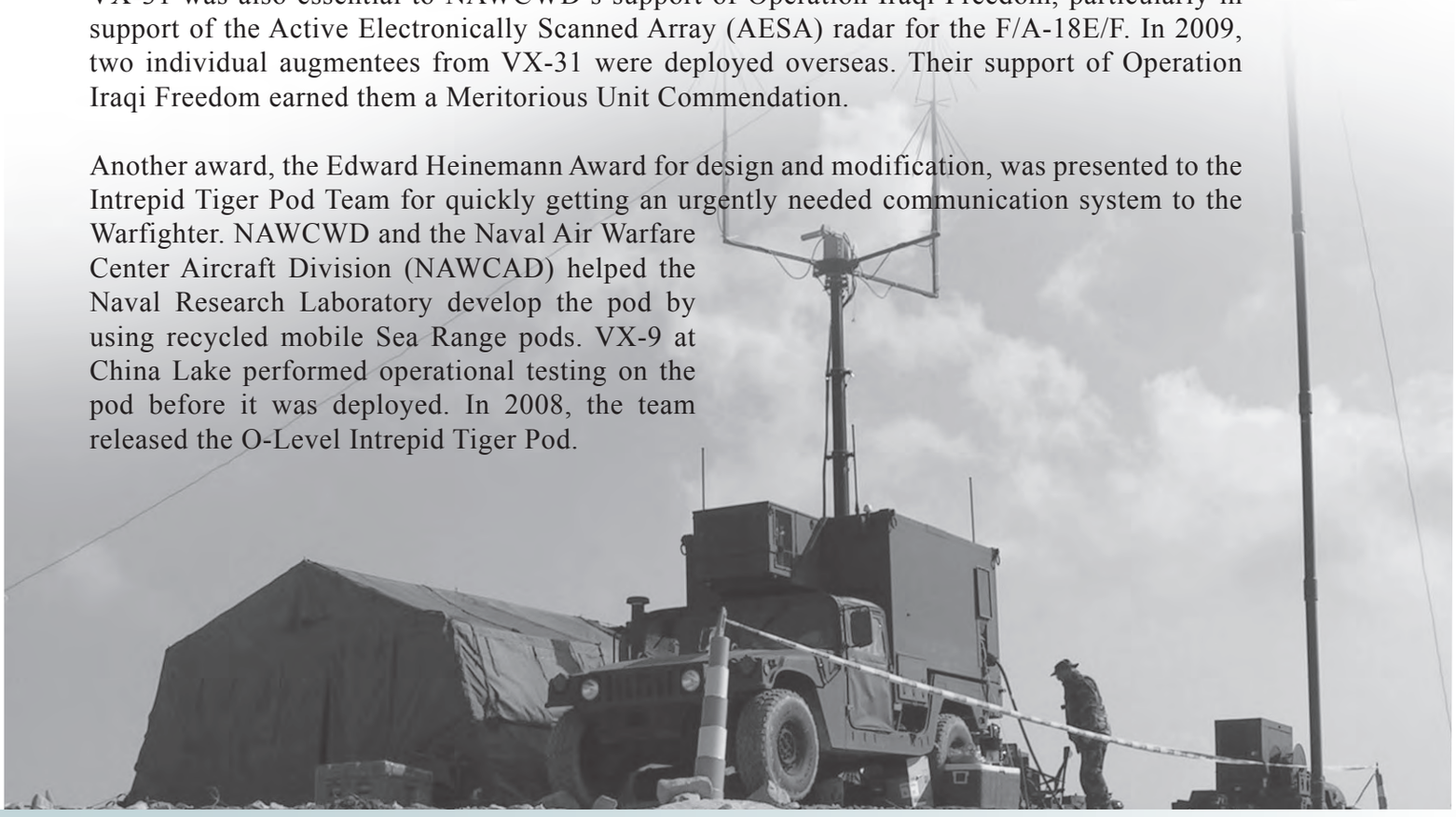
PSS-SOF significantly increased targeting capability and quickly became the targeting system of choice for both GPS- and laser-guided weapons deployed for close-air support missions, troops in contact missions, and time-sensitive missions. In 2007, three RAIDER systems were deployed to Iraq and Afghanistan, and NAWCWD civilian engineers supported them in theater. For example, the RAIDER team provided USS *Harry S. Truman* with Link-16 capability based on a RAIDER Ground Mobile Gateway System. SHARP was approved for early deployment and provided real-time high-resolution images to ground forces in northern Iraq. SHARP also allowed the central computer on USS *Abraham Lincoln* to download images from F/A-18s and convert them to weapon targeting coordinates.

The ECR at China Lake supported a Joint Fleet Exercise (JTFEX) with USS *John C. Stennis*. Two tent cities, representative of the current conflict, were constructed at Charlie Airfield to provide realistic areas of opportunity for EW-opposed strike missions. The Joint Electronic Warfare Effects Laboratory also provides important EW-related support; for example, in 2009, it completed 59 critical tests that resulted in direct changes to operations.

VX-30 was often sent in theater to support the War on Terror. For example, a crew from VX-30 was tasked with flying a C-130 to Iraq and preparing it to launch five drone aircraft at Baghdad. VX-30 Hornets also flew in support of USS *Abraham Lincoln*, USS *Carl Vinson*, USS *Nimitz*, USS *Ronald Reagan*, and USS *Peleliu*. In 2009, VX-30 deployed four personnel to the Central Command, Atlantic Ocean Range.

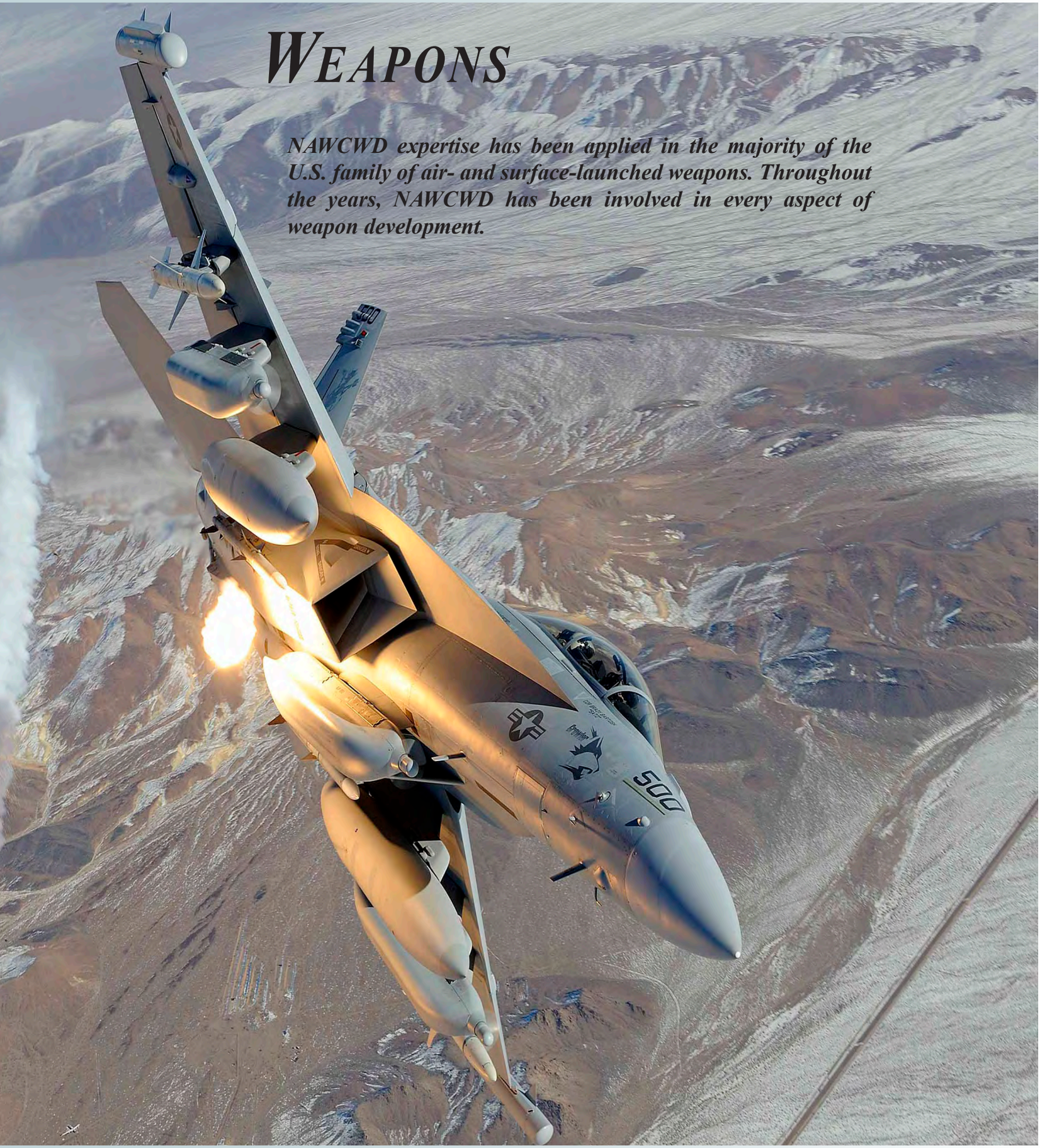
VX-31 was also essential to NAWCWD's support of Operation Iraqi Freedom, particularly in support of the Active Electronically Scanned Array (AESA) radar for the F/A-18E/F. In 2009, two individual augmentees from VX-31 were deployed overseas. Their support of Operation Iraqi Freedom earned them a Meritorious Unit Commendation.

Another award, the Edward Heinemann Award for design and modification, was presented to the Intrepid Tiger Pod Team for quickly getting an urgently needed communication system to the Warfighter. NAWCWD and the Naval Air Warfare Center Aircraft Division (NAWCAD) helped the Naval Research Laboratory develop the pod by using recycled mobile Sea Range pods. VX-9 at China Lake performed operational testing on the pod before it was deployed. In 2008, the team released the O-Level Intrepid Tiger Pod.



“I can tell you that systems developed and tested at WD [the Weapons Division] played a critical role in our success in Fallujah, including DPSS, TDM [Tactical Dissemination Module], and the F/A-18 aircraft integration of the GBU-38, the 500-pound JDAM. I personally witnessed a GBU-38 surgical strike take out a building being used by insurgents in a crowded neighborhood, while leaving the buildings next door unharmed. The work done at WD is making a difference in the War on Terrorism.”

—Captain Dan Lee
Military Director, Weapons and Energetics Department



WEAPONS

NAWCWD expertise has been applied in the majority of the U.S. family of air- and surface-launched weapons. Throughout the years, NAWCWD has been involved in every aspect of weapon development.

Weapons

Advanced Anti-Radiation Guided Missile (AARGM)

The AARGM is an enhancement kit for the HARM and is the next-generation ARM. The kit mates a completely new dual-mode anti-radiation homing and millimeter wave terminal guidance section and a modified control section with GPS/inertial navigation system (INS) capability to the rocket motor, airframe, and warhead of an AGM-88B/C. NAWCWD served as the lead technical field activity, as well as the lead for T&E in captive and live fire scenarios.

Advanced Medium-Range Air-to-Air Missile (AMRAAM)

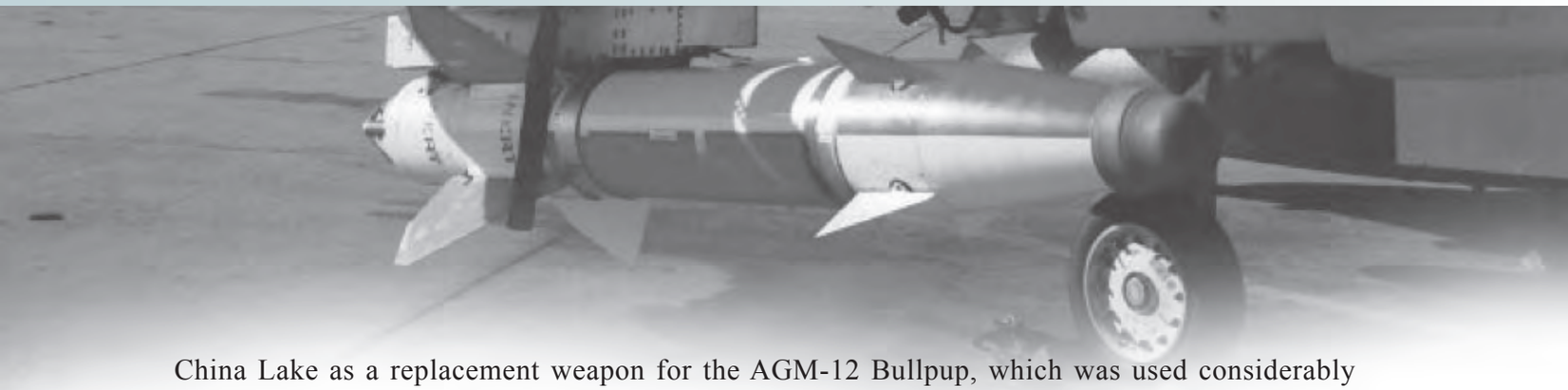
The AIM-120 AMRAAM is an all-aspect medium-range air-to-air radar-guided missile designed for air superiority. Specifically, the AMRAAM targets threat air superiority fighters. NAWCWD's current role includes development and engineering support, T&E, platform integration, and Fleet logistics and training. Specific China Lake milestones include the first AMRAAM fired from an F-22 and EA-18G.

Antisubmarine Rocket (ASROC)

The ASROC is a quick-reaction all-weather intermediate-range antisubmarine warfare (ASW) weapon launched from surface ships. ASROC consists of a torpedo, a double-base propellant rocket motor, an ignition separation assembly, and a dome-shaped plastic nose cap that protects the torpedo's transducer assembly as the weapon enters the water. The system became operational in 1961 and was used frequently during the Vietnam conflict. In 1964, China Lake upgraded the ASROC to double the missile's standoff range and increase its delivery accuracy. In the early 1970s, China Lake helped to develop the Vertical Launch ASROC (VLA), which was an improved rocket-propelled ASW weapon that is designed for deployment on ships equipped with the Mk 41 Vertical Launching System. The VLA uses a larger rocket motor with a jet vane thrust vector control system and an onboard digital autopilot to ensure accurate, extended-range delivery from the vertical launch mode. NAWCWD continues to support propulsion steering technology through the ongoing Compact Low-Cost Thrust Vector Control Program and is also engaged in programs using jet vane technology, including the Sidewinder AIM-9X and the ESSM. Thrust vector control technology is also an important part of the Standard Missile-3 Third-Stage Rocket Motor, a key element in the Navy's Sea-Based Theater Ballistic Missile Defense Program.

Bulldog

The AGM-83 Bulldog was an air-to-surface laser-guided missile designed for use in close-air support by the U.S. Marine Corps. Bulldog's large delivery envelope, long-range and low-altitude fire capability, and low cost made it ideal for destroying small ships, bridges, tanks, and similar stationary and mobile targets. The AGM-83 was conceived, designed, and developed by



China Lake as a replacement weapon for the AGM-12 Bullpup, which was used considerably in Vietnam but had several operational problems. Designed around the Bullpup airframe, the Bulldog incorporated components from existing weapon systems wherever possible, including a significant amount of Sidewinder technology for the guidance system.

Condor

The AGM-53 Condor was a long-range air-to-surface television-guided supersonic cruise missile designed to provide the U.S. Navy a standoff capability against heavily guarded, high-value, and strategic targets. China Lake was the lead field activity and technical manager responsible for initial development and also provided the technical direction for the dual-mode seeker, turbojet design, systems engineering, guidance, fuzing, warhead development, system safety, propulsion, aircraft interface, and cost analysis.

The "Eye" Series

In its capacity as the Navy's lead laboratory for free-fall weapons, China Lake developed the "Eye" series of weapons in the early 1960s to improve the Navy's air-attack capability. Weapons in the "Eye" series include Briteye, Deneye, Fireye, Gladeye, Padeye, Sadeye, and Snakeye; however, Walleye and Rockeye (specifically the Mk 20 Rockeye II cluster bomb unit [CBU]) stand out as having had the greatest impact on the Fleet. Conceived, designed, developed, and tested by China Lake in the early 1960s (the weapon was fielded in 1967), Walleye was the first precision-guided air-to-surface weapon. The Mk 20 Rockeye II CBU is an unguided free-fall cluster weapon intended for use against tanks and armored vehicles. Rockeye serves as the backbone for the CBU-59 Antipersonnel/Anti-Materiel (APAM) and CBU-78/B Gator bombs, which are still in service today.

Fat Man and Little Boy

China Lake was a major contributor to the success of the Fat Man and Little Boy during World War II. The China Lake and Caltech Team were tasked to develop the nonnuclear explosive components of the atomic bomb. China Lake also performed detonator testing; mixed, melted, cast, and machined explosive shapes; air-dropped hundreds of bomb components and shapes from B-29 bombers; studied and solved flight problems; and conducted aeroballistic tests to optimize aerodynamics and to test fuze functions. The team also evaluated equipment procedures to be used in the tactical delivery of the atom bomb. Aerodynamically, the early bomb configurations were incapable of accurate flight. Hundreds of drop tests with different fins and weight distributions were required to solve the problem. This work was conducted at China Lake and several other sites around the country. Only dummy bombs (no nuclear warheads) were dropped at China Lake. Sea testing was also conducted to determine whether the shock would detonate the weapons in case Fat Man or Little Boy was jettisoned at sea.

Fleet Ballistic Missiles

Fleet ballistic missiles are large long-range submarine-launched missiles equipped with nuclear warheads. China Lake's development efforts advanced thrust vector control systems, propellant efficiency and safety, and technology for large rocket motors.

Fuel-Air Explosive (FAE) Weapons

FAE weapons use an explosive charge to create an aerosol cloud of fuel in the air, which is then ignited by a detonator, thereby creating high overpressure useful against soft targets in protected areas, such as personnel in trenches, as well as clearing mine fields and landing zones. China Lake had full-spectrum capability on several FAE weapons, including the CBU-55A/B, CBU-72/B, BLU-95, BLU-96, APAM, and several others.

Gator

Gator is an antipersonnel, antitank air-to-surface unguided munitions delivery system used by the U.S. Navy, Marine Corps, and Air Force against area targets such as tanks, armored vehicles, trucks, radar installations, SAM sites, parked aircraft, and other materiel. Gator is the successor of Deneye, an antitank mine delivery system developed by China Lake in the early 1960s as part of the "Eye" series of free-fall weapons. NAWCWD is currently responsible for in-service engineering and logistics support.

General Purpose Bombs

The Mk 80 weapon series, which include the 250-pound (Mk 81), 500-pound (Mk 82), 1,000-pound (Mk 83), and 2,000-pound (Mk 84) bombs, are free-fall air-to-surface unguided general purpose bombs. China Lake and Point Mugu have been actively involved with RDT&E of bombs since World War II. Consequently, China Lake became the Navy's lead laboratory for free-fall weapons in the early 1960s.

Harpoon

The AGM/RGM/UGM-84 Harpoon is an autonomous all-weather over-the-horizon antiship missile system providing the Navy and Air Force with a common missile for air, ship, and submarine launches. Harpoon is a fire-and-forget missile system using both inertial and active-radar guidance. The blast warhead is effective against a wide variety of targets, including ships at sea and in port, coastal defense sites, SAM sites, exposed aircraft, and port and industrial facilities. Although the U.S. Navy orders ceased, Harpoon upgrades will continue to 2015. The missile also continues to be one of the most widely exported Navy weapon systems, with more than 30 allied nations fielding the system.

Hellfire

The AGM-114 Hellfire (Heliborne Laser Fire and Forget) is a close-in point defense air-to-surface precision-guided missile designed to engage tanks and armored vehicles, both stationary and moving. In general, China Lake's Tactical Weapons Office serves as assistant program manager for systems and engineering and as class desk for NAVAIR's Defense Suppression Systems Office. Point Mugu serves as assistant program manager for logistics and as the Fleet support team for integrated logistics support services of Hellfire. In particular, China Lake developed the MAC warhead used in the AGM-114N. In addition to the MAC warhead, China Lake continues to support development of the AGM-114R to ensure that it meets Navy requirements, specifically in relation to Military Operations in Urban Terrain targets.

High-Speed Anti-Radiation Missile (HARM)

HARM is an air-to-surface guided anti-radiation missile for the suppression of enemy air defense. The HARM was designed to address the deficiencies in Shrike and to incorporate new technologies to engage modern, constantly evolving threats. NAWCWD remains the technical lead for HARM and is responsible for legacy HARM software updates.

Joint Air-to-Ground Missile (JAGM)

The JAGM is intended as a replacement missile for Hellfire; Maverick; and the Tube-Launched Optically Tracked Wire-Guided missiles on rotary-wing, fixed-wing, and unmanned platforms. The JAGM is intended to engage a variety of targets, including advanced heavy/light armored vehicles, bunkers, buildings, naval patrol craft, command and control vehicles, transporter/erector launchers, artillery systems, and radar/air defense systems. NAWCWD plays a significant supporting role for each of the contractors in the JAGM Program, provides personnel for Integrated Product Teams, working groups, and failure

review boards, as well as providing contractor analysis documents, white papers, technical guidance documents, and supporting research.

Joint Direct Attack Munition (JDAM)

The JDAM is a low-cost strap-on GPS/INS guidance kit that converts free-fall air-to-surface unguided bombs, or "dumb" bombs, into accurately guided "smart" munitions. NAWCWD serves as the Navy's lead field activity for JDAM, while also providing Fleet technical support, as well as support for contractor testing, mission planning and development, and logistics. NAWCWD played a major role in the integration of JDAM on several platforms, including the F/A-18C/D/E/F; the F-14B/D; the AV-8B; and, in 2009, the MQ-9 Reaper. NAWCWD also helped field the Laser Joint Direct Attack Munition (LJDAM) system in October of 2008.

Joint Multi-Effects Warhead System (JMEWS)

The JMEWS is a long-range weapon system that provides increased flexibility and lethality in denied environments against hardened targets. This warhead technology will provide a leap-ahead capability against a widely varied target set, which includes hard and soft targets. Currently, the JMEWS warhead is being integrated into a Block IV Tomahawk missile because the warhead's extended operating range and in-flight command and control are critical to successfully mitigating identified capability gaps. Other platforms may be considered for future follow-on acquisition after the JMEWS warhead design is optimized and successfully flight tested. NAWCWD China Lake is the Navy's lead T&E agent on the JMEWS project and provides fuzes and technical support. The production warhead is tentatively scheduled to be introduced to the Fleet in 2014/2015.

Joint Standoff Weapon (JSOW)

The AGM-154 JSOW is a standoff-outside-point-defense air-to-surface laser-guided glide weapon used to engage a variety of targets, depending upon the variant employed. JSOW comes in three main variants: the baseline version, which deploys 145 bomblets for area targets; the antiarmor version, which carries six bomblets for armored targets; and the unitary version, which has a dual-stage warhead for blast/fragmentation and penetration of point targets. China Lake provides support for systems engineering, flight test planning, logistics and training, and developmental and operational testing and conducts Fleet introduction and interface; in fact, the first flight test took place at China Lake in 1994.

Laser-Guided Bombs (LGBs)

LGBs are air-to-surface precision-guided bombs designed for use against all types of surface targets. As the name implies, LGBs use a nose-mounted laser guidance and control system in concert with tail fins to direct the weapon to the target. China Lake's work with LGBs began in the late 1960s while helping the Air Force adapt its Pave Knife laser target designator pod to the Navy's A-6 aircraft. In the 1980s, China Lake developed a rocket-propelled version of the GBU-16 that went into production in 1985 as the AGM-123 Skipper. More recently, NAWCWD designed, tested, and built the BLU-116A/B warhead for the hard-target penetrator LGB designated GBU-24G/B and developed the Dual-Mode Laser-Guided Bomb (DMLGB).

Maverick

The AGM-65 Maverick is a standoff-outside-point-defense air-to-surface guided missile used against a variety of targets. Today, China Lake's Tactical Weapons Office serves as assistant program manager for systems and engineering and class desk for the NAVAIR Defense Suppression Systems Office. In that capacity, China Lake supports the Navy and Marine Corps variants from cradle to grave. Point Mugu serves as assistant program manager for logistics and as the Fleet support team for integrated logistics support. NAWCWD is currently lending its support to the Enhanced Laser Maverick (AGM-65E2) Program initiated to address the need for a close-air support weapon capable of engaging moving targets.

Phoenix

The AIM-54 Phoenix was an all-weather long-range air-to-air radar-guided missile designed to counter the threat of Soviet bombers attacking naval carriers. In the 1980s, the Navy developed the Phoenix into an extended-range air-to-air missile called the Advanced Air-to-Air Missile. However, with the end of the Cold War in 1990, the threat of Soviet bombers was significantly diminished, a situation that, in turn, dramatically reduced the need for a missile of this kind. Therefore, in 1992, the program was canceled.

Polaris

The UGM-27 Polaris was a solid-propellant SLBM that had two stages of propulsion. Polaris A-1 weighed 28,800 pounds and had a range of approximately 1,000 nautical miles. Overall, the Polaris Program was one of China Lake's most significant areas of accomplishment in Fleet ballistic missile support. The Polaris studies conducted by China Lake were instrumental in the development of the concept and the weapon system.

Regulus

Regulus was developed in the late 1940s to meet the Navy's requirement for a long-range submarine-launched bombardment weapon. Regulus I was a 500-mile-range surface-to-surface subsonic guided (cruise) missile that began testing at Point Mugu in 1949. The Regulus II had a range of 1,380 miles and was initially boosted by a rocket motor and then powered by a 10,000-pound-thrust turbojet engine to a speed of Mach 2. Regulus came to Point Mugu for T&E in January 1949 and became the largest single program in Point Mugu history in terms of manpower and facilities. The last Regulus II target drone was flown in 1965.

Revolutionary Approach to Time-Critical Long-Range Strike (RATTLRS) Program

The RATTLRS effort is a Navy-led flight demonstration project to develop advanced technologies for turbine-powered expendable flight vehicles that can travel at supersonic speeds exceeding Mach 3. The RATTLRS concept involves a highly integrated supersonic air vehicle with an inlet and nozzle system. This weapon incorporates an expendable turbine propulsion system, whose size, shape, and weight are traceable to a joint tactical expendable weapon system. NAWCWD is tasked with the chief engineer functions, tactical weapons traceability, aeromechanical design support, flight test planning, and flight range supporting operations. NAWCWD continues T&E efforts, and the RATTLRS flight test program is being completed.

Rockets

Rockets are air- and surface-launched unguided ballistic trajectory weapons propelled by the controlled burning of energetic materials. China Lake developed the Zuni rocket, a 5.0-inch air-to-surface unguided folding-fin rocket developed in the 1950s. The Zuni was initially intended for air-to-air combat but later evolved into an air-to-surface weapon. China Lake also developed a 2.75-inch air-to-air rocket nicknamed Mighty Mouse. Like the Zuni, the Mighty Mouse is an unguided folding-fin rocket. This rocket remains one of the most fired weapons in history, surpassed only by bullet-type ammunition.

Rolling Airframe Missile (RAM)

The RIM-116A RAM is a lightweight, quick-reaction, high-firepower surface-to-air weapon designed to counter antiship missiles. The RAM is a 5-inch passive dual-mode RF and IR fire-and-forget missile that uses Sidewinder technology for the warhead and rocket motor. Because of its high-tech guidance system, RAM requires no shipboard support after the missile is launched. RAM is effective against a wide spectrum of threats and supplements Phalanx and SeaSparrow in the ship's defensive arsenal. China Lake is the design agent for developing the rocket motor for the RAM Block II kinematic upgrade design. In 2008, it was determined that the upgrade design was ready for implementation, integration, and verification. The NAWCWD Sea and Land Ranges continue to be used for operational and development testing. A capability against helicopter, aircraft, and surface targets is currently being developed, and operation evaluation occurred in 2005. SeaRAM is also being developed for smaller ships, and, in 2008, a SeaRAM system was installed on USS *Independence*.

SeaSparrow

The SeaSparrow SAM system, which was based on the original air-to-air Sparrow missile, can destroy hostile aircraft and antiship missiles. The SeaSparrow has a low-altitude guidance system that is effective against very-low sea-skimming cruise missiles. Since 1991, NAWCWD has served as the technical direction agent on the SeaSparrow Program. By 1995, engineering and manufacturing on the ESSM began. The ESSM was a kinematic improvement to the SeaSparrow, with a primary mission of destroying highly maneuverable low-altitude antiship cruise missiles. RIM-162 ESSM entered low-rate initial production in 2003, with NAWCWD continuing T&E.

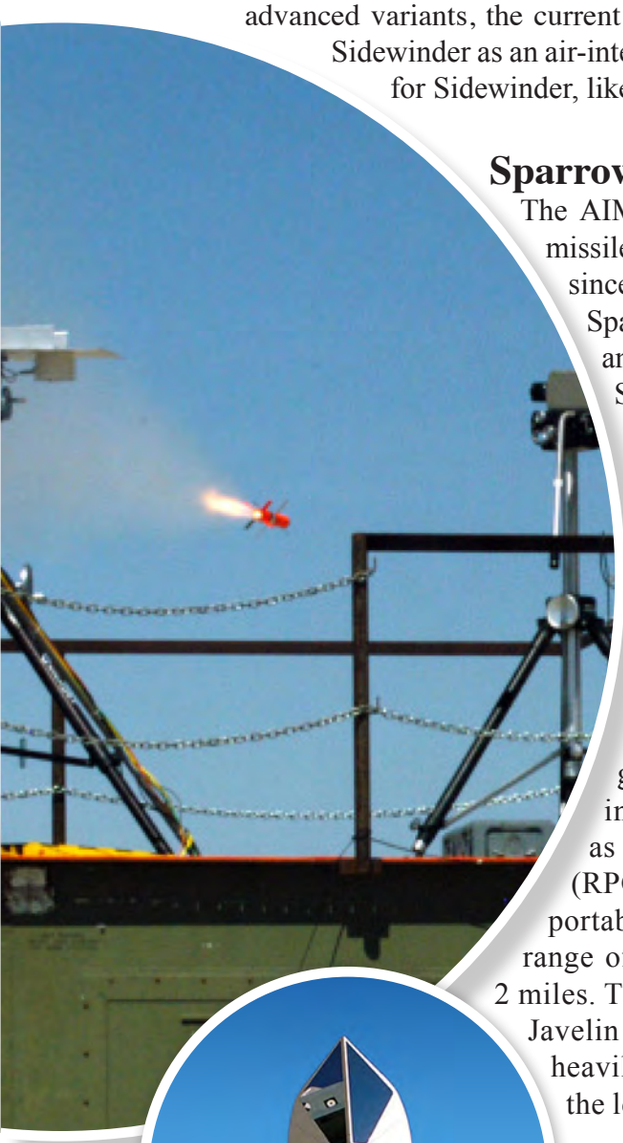
Shrike

The AGM-45 Shrike is a passive-homing air-to-ground ARM designed to suppress enemy air defense. Conceived, designed, developed, and tested by China Lake, Shrike was the first U.S. anti-radiation missile to be mass produced. Most notably, China Lake pioneered anti-radiation guidance employed by Shrike and its successors.

Sidewinder

The AIM-9 Sidewinder is a short-range air-to-air guided missile used to engage all types of jet aircraft and helicopters. China Lake conceived, designed, and developed the Sidewinder in the early 1950s under the direction of Dr. William B. McLean and continues to employ a similar full-spectrum capability today. The basic Sidewinder airframe shape and design remain essentially unchanged since the first-generation variant, the AIM-9B. However, there is a continuing product improvement program constantly devising new and

advanced variants, the current being the AIM-9X. In addition to the linear developmental path of Sidewinder as an air-intercept missile, there are also a few divergent paths that led to new uses for Sidewinder, like SideARM, RAM, and Chaparral.

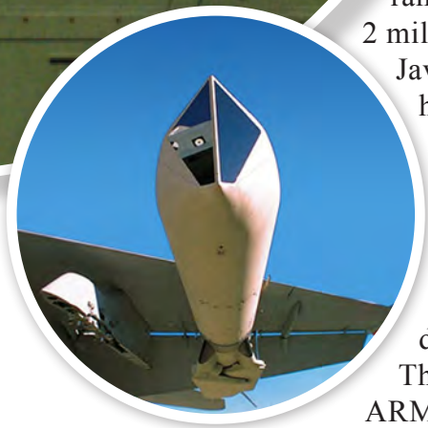


Sparrow

The AIM-7 Sparrow is an all-aspect medium-range air-to-air radar-guided missile. Point Mugu was involved in evaluating every variant of Sparrow since its inception. Those efforts included the first successful test, in which Sparrow I rode a radar beam; the first air launch of Sparrow I, II, and III; and the first kill for all three variants. China Lake began working on Sparrow in the early 1970s, after its disappointing performance during the conflict in Vietnam. Today, most of NAWCWD's efforts with Sparrow focus on the SeaSparrow and the ESSM.

Spike

Spike is a man-portable fire-and-forget guided missile and launcher system that is very low cost and lightweight. Highly effective against helicopters and lightly armored vehicles, Spike is a boon to warfighters in urban assault scenarios. Originally conceived and developed at China Lake, Spike is the smallest guided missile in the world, at 25 inches in length and 2.25 inches in diameter, with a weight of 5.3 pounds. The system is envisioned as a safer, more-accurate alternative to rocket-propelled grenades (RPGs) and as a relatively inexpensive complement to the man-portable Javelin antitank missile. Compared to unguided RPGs with a range of only a few hundred yards, Spike has a range of approximately 2 miles. The cost of a Spike missile is also significantly less than that of the Javelin missile, thereby allowing the more costly missile to be used for heavily armored targets. The cost goal of $5,000 per unit makes Spike the lowest-cost guided missile in existence. Further T&E are continuing.



Standard Missile

Standard Missile is the Navy's primary surface-to-air Fleet defense weapon and is widely deployed on Navy ships. Standard Missile began development in 1964, entered service in 1968, and has steadily evolved. The three main subtypes included the Standard Missile-1, Standard ARM, and Standard Missile-2. The Standard Missile-2 Block I was an all-weather ship-launched medium-range air defense missile with added midcourse command guidance to increase area coverage. China Lake maintains a computer-in-the-loop facility for software development and target-detecting device (TDD) tests. NAWCWD developed and maintains a new engineering simulation, GENSIM, used to predict the performance of the Mk 45 TDD. NAWCWD conducted blow-down wind tunnel tests to qualify the Mod 9, 10, and 14 TDDs. For the cancelled Standard Missile Block IVA Program, NAWCWD developed an accurate method of field testing forward-looking fuzes by using artillery shells as targets and provided

consultation on IR seeker development. NAWCWD is also funded to develop new safety and arming technology using microelectromechanical systems (MEMS) technology. NAWCWD also supports the development and testing of the Standard Missile-3, a variant of the Standard Missile that fires from an Aegis cruiser to intercept a ballistic missile in the exo-atmosphere.

Standoff Land Attack Missile (SLAM)

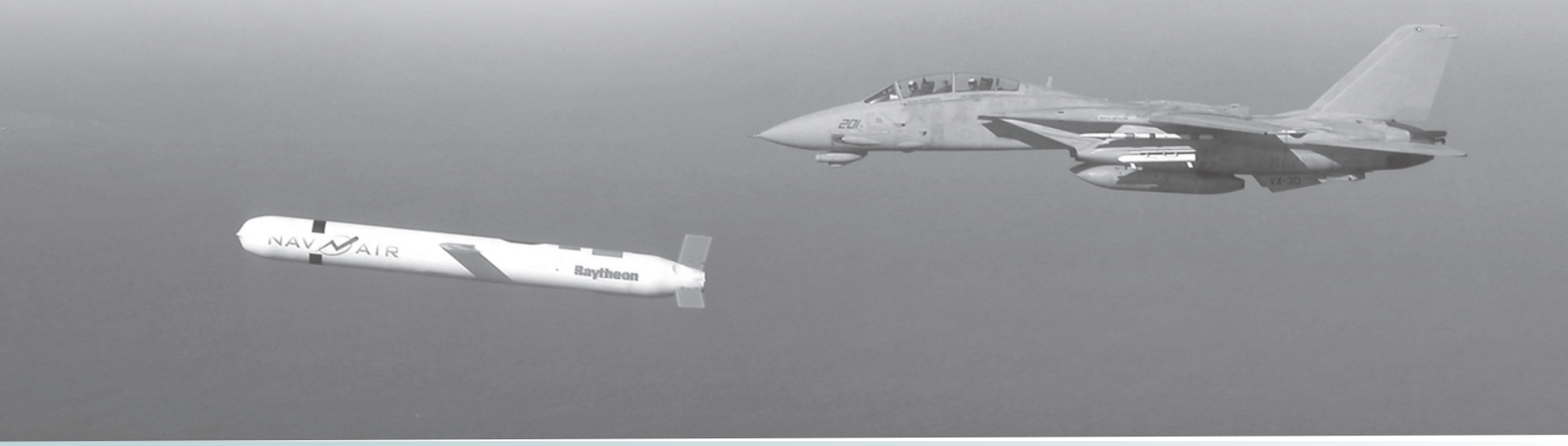
The AGM-84E SLAM is a standoff-outside-area-defense air-to-surface missile. Its primary targets include high-value/time-critical land targets in high-threat areas and ships in port. NAWCWD wrote the system specification and statement of work for the initial concept of SLAM and was involved in all engineering efforts from conception through full-rate production. Because of the SLAM's performance record in combat, China Lake was tasked with increasing its capabilities. This effort resulted in the Standoff Land Attack Missile–Extended Response (SLAM-ER), which was released in 2000.

Tomahawk

Tomahawk is a long-range surface-to-surface guided subsonic cruise missile used for land attack from submarines and surface ships, often against high-value assets in high-threat areas. Tomahawk has two warhead configurations: a 1,000-pound blast/fragmentation unitary warhead and a general purpose bomblet dispenser. China Lake is the Navy's principal support activity for the Tomahawk, the acquisition engineering agent for the all-up round, the software engineering agent and the engineering design agent for the Tactical Tomahawk Penetrator Variant warhead.

Trident

Selected in 1975 to build a Trident SLBM operational test range in the Pacific, Point Mugu designed and installed the Trident Missile Test Instrumentation System, which was the most complex and extensive range system ever assembled at Point Mugu. The system became operational in 1983 and provided test forces with real-time range safety displays, underwater submarine tracking, in-flight tracking of up to four missiles, instantaneous impact predictions, and recording and display of missile telemetry. China Lake continues to evaluate the Trident propellant aging properties to help the Navy understand the quality and reliability of the Trident weapon inventory. China Lake is also involved in the Trident D-5 Service Life Extension Program, which seeks to find alternative sources of supply and qualify new component production methods.



> We are exploring the outer boundaries of science and technology, as well as the conventional aspects. We do not hesitate to direct our attention to what we believe will be the principles and practices of tomorrow, and we try to organize them in order to better direct the programs of today.

—Dr. Royal Weller, first civilian Chief Scientist at NAMTC, Pt. Mugu

Unmanned Systems (UxS)

Unmanned Systems (UxS)

Mission. NAWCWD is one of the Navy's foremost activities that field UxS. Several teams, including the Unmanned Systems Activity (USA), are involved with this UxS effort. The USA is responsible for UxS in all domains—air, ground, surface, and subsurface—and provides all the components needed to launch, control, and recover these systems. In addition, NAWCWD is a technical lead for UxS sensors, weapons integration, cost and effectiveness analyses, and T&E.

In fiscal year 2011, UxS efforts outpaced those for manned systems in terms of total flight hours accumulated and revenue generated for the China Lake Land Ranges. UxS work is a strategic thrust area for NAWCWD, and UxS work continues to grow.

NAWCWD—Current UxS Role

NAWCWD Combat Support

NAWCWD personnel integrated, tested, and qualified for flight a number of specialized unmanned air system payloads to support combat operations in Operation Enduring Freedom and Operation Iraqi Freedom. The integrations were conducted as rapid acquisition projects—each being completed in less than 18 months. These systems are regularly used to support combat operations. Additional prototypes and integration of new capabilities have been requested.

UAV Success in War on Terror, Osama bin Laden

According to a May 17, 2011 article in the *Washington Post* entitled, "CIA flew stealth drones into Pakistan to monitor bin Laden's house," the United States employed sophisticated new stealth drone aircraft to fly dozens of secret missions to monitor the compound where Osama bin Laden was eventually killed. Drones provided high-resolution video that satellites could not provide. The article explained that drones were also used on the night of the raid, providing useful imagery for President Obama and his national security team. The new drones represent a major advance in the capabilities of remotely piloted planes, which have been the signature weapon against terrorism since September 11, 2001. As one of the Navy's foremost activities to field UxS capabilities, NAWCWD is proud to be part of a national DoD team developing new tools for today's warfighters.

UxS Full-Spectrum Support

There are few places in the nation where UxS customers can enjoy full-spectrum (cradle-to-grave) UxS RDT&E support. Regardless of the stage of development, from new unproven systems to battle-tested systems pushing the weapons test envelope, NAWCWD can handle any requirements. Whether the customer needs large time and airspace blocks for sensor operator training or multiple weapon launch scenarios, NAWCWD supports many concurrent operations. In addition, NAWCWD controls military restricted airspace, so authorized customers do not need to obtain an FAA certificate of authorization to operate UAVs on the ranges.

Intellectual Capital
With more than 2,000 science and engineering professionals (47% of workforce) and more than 600 science and engineering technicians (15% of workforce), including 100+ PhDs and 600+ employees with master's degrees, NAWCWD has the highly advanced intellectual capital necessary to respond to any urgent DoD or contractor requirement.

Cost Efficiencies/Optimum T&E Weather
Benefitting from more than 350 clear days per year, NAWCWD has optimum meteorological conditions that few UxS testing locations nationwide can match. If there is a technical problem, a customer can reschedule to fly the next day, if necessary. Customers save time and money by testing in one location.

UxS Weaponization
The UxS field has evolved so rapidly that there has been very little standardization. There are a multitude of size designs, ranging from very large platforms (equivalent to airliners) down to vehicles that can fit in the palm of a hand and can fly over land and sea, and some that operate in undersea environments. Therefore, engineers are considering all possibilities across a broad spectrum when developing future weapon options.

Forward-Firing Miniature Munition (F2M2) (Formerly Called Spike). China Lake is credited with developing the world's smallest guided missile, the F2M2. Weighing about 6 pounds, this fire-and-forget missile is approximately 24 inches in length and is suitable for a variety of unmanned and manned systems; it is accurate and portable—designed to be shoulder- or platform-launch capable.

Miniature Guided Bomb Unit (MGBU). Engineer teams are researching and developing the MGBU, a miniaturized gravity bomb for line-of-sight applications. The MGBU weighs less than 4 pounds and is designed for accuracy, with minimal collateral effects. It can be utilized by small UAVs such as the small tactical unmanned aerial system (STUAS) and RQ-7 Shadow.

GPS-Guided Miniature Munition (G2M). Engineers are developing a 40-millimeter-sized precision miniature munition called the G2M for non-line-of-sight applications. It is intended to be compatible with shoulder- or platform-launched applications. G2M is undergoing navigation testing and development of other critical system components and subsystems. Future development options may include integration of sensors and components to expand capability and increase range.

The F2M2, MGBU, and G2M are being developed to provide small UxS and dismounted forces with a standoff precision engagement capability with minimal collateral effects.

UxS Payload Integration—System-of-Systems Standards-Based Approach

UxS platforms require multiple payload capabilities with various size, weight, and power constraints. Since point solutions are often unaffordable and unsustainable, China Lake designed, built, and applied system-of-systems engineering to develop a standards-based stores management approach that is both platform and payload agnostic. The small, lightweight, low-power, interoperable system can be

integrated across domain platforms for strike and force protection with many payloads—including nonlethal weapons. In addition, NAWCWD has made significant advances in MEMS, nanotechnology, micro-explosives, and super-capacitor technology that are significantly reducing the size and weight power supply requirements for UxS. Nanoplasmonics and metamaterials accommodate the need for miniaturization of optoelectronic components that are critical to reduce the footprint and weight of future weapon systems. With more than a dozen unmanned combat system firsts in the industry, NAWCWD maintains a strong leadership position in the UxS battlefield of tomorrow.

Shipboard Efforts

- Performed ship integration efforts for Pioneer; maritimized vertical takeoff-and-landing UAV system (MAVUS); Tactical Air-Launched Decoy (TALD) and Improved Tactical Air-Launched Decoy (ITALD)
- Performed shipboard flight certification and operational demonstration with MAVUS
- Performed shipboard operations with Fire Scout unmanned aerial system (UAS)

Naval Integrated Operations

- Integrated Predator UAS flown from San Nicolas Island into Fleet Composite Training Unit Exercise 96-1A for training exercise surveillance, reconnaissance, mini-strike (day and night), and mobile target track support
- Integrated Predator, ScanEagle, and Raven UAVs into Tomahawk operational test launch, an effort that allowed for tactical targeting and battle damage assessment
- Demonstrated successful tactical control system (TCS) level 5 command and control (using Block 0 with Predator, Block 2 with Fire Scout)
- Participated in the unmanned combat air vehicle (UCAV) integration for Predator/Reaper Hellfire, GBU-32, and Fire Scout Hydra 2.75-inch rockets
- Support and host Black Dart counter-UAS flight operations on an annual basis
- Conduct flight test programs for the entire array of UxS

NAWCWD UxS Firsts

First Flights

- Northrop Grumman Corporation's RQ-8 (Fire Scout) and X-47A (Pegasus)
- FAA-authorized transcontinental flight from Patuxent River to Point Mugu by Northrop Grumman Corporation's Global Hawk
- Navy's ScanEagle

First Launches

- AGM-114P against moving target from Army Sky Warrior; single AGM-114 (Hellfire) off MQ-1 (Predator A); and ripple fire of AGM-114s from MQ-9 (Predator B)
- Air-to-Air Stinger from MQ-1

First Releases

- GBU-39 JDAM from MQ-9 (Reaper)
- GBU-12 (Paveway II) from MQ-1 and MQ-9 (Reaper)
- GPS-guided small smart bomb (SSB) from the Boeing X-45A

Other Noteworthy Firsts

- First to support UAV search and rescue on land and at sea with Predator B
- First full power GPS jamming testing against MQ-9

UxS Flown/Tested on NAVAIR Ranges

UxS Land Range Testing

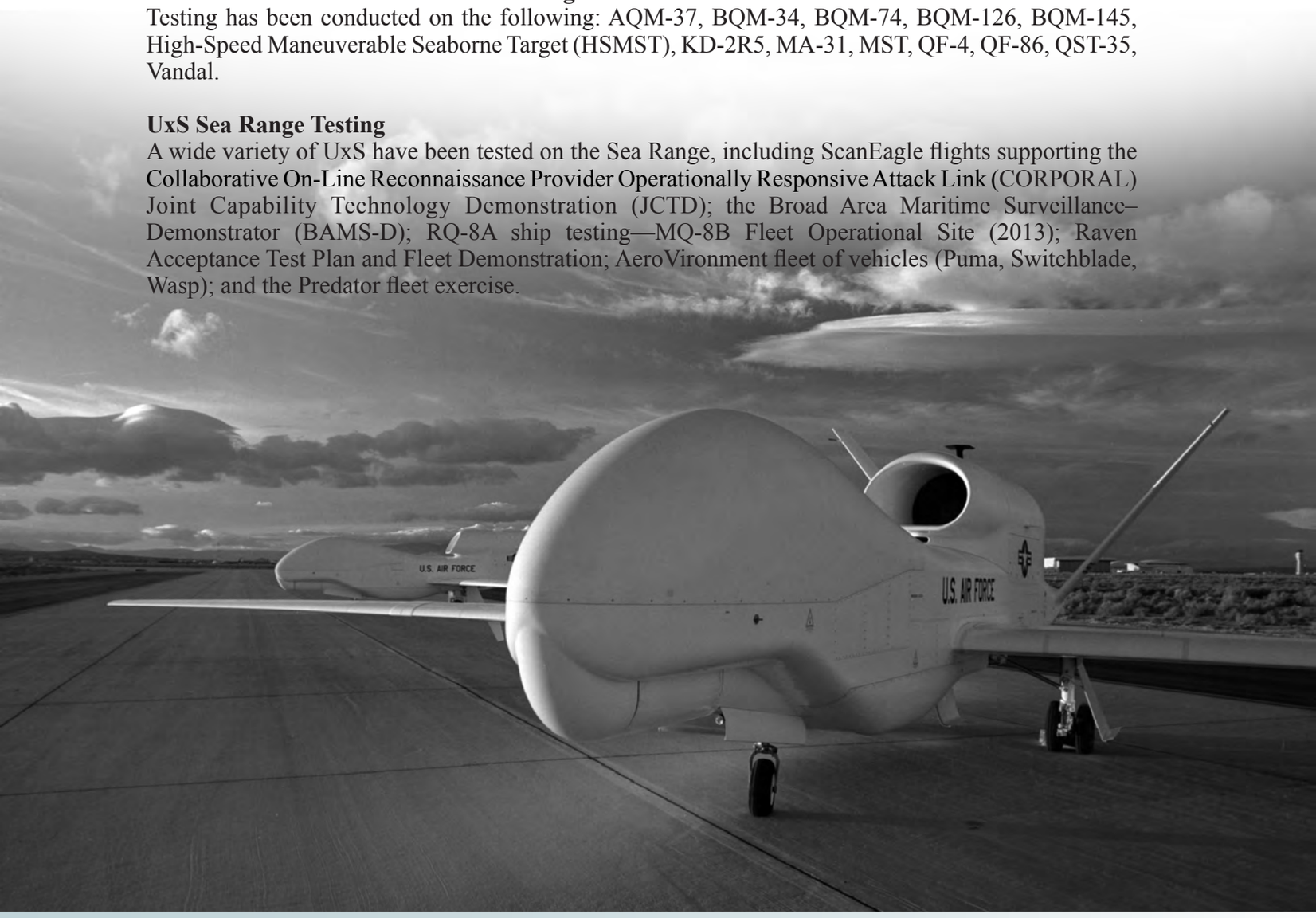
The following have been flown/tested on NAVAIR ranges: AeroLite, Aerosky, Aerosonde, Amber, Dakota, Dragon Eye, Exdrone, Falcon Prowl (United Kingdom), Fire Scout, Global Hawk, Global Observer, Hunter, Joint Unmanned Combat Air System (J-UCAS) X-45A, MAVUS, Medium-Altitude Endurance UAV (MAE UAV) (MQ-1, MQ-9), Micro Air Vehicle, Pegasus, Pioneer, Pointer, Predator, Raven, Reaper, REECE, ScanEagle, Shadow, Sky Owl, Sky Warrior, Swift, Switchblade, TALD, TCS, Tilt Rotor UAV System (TRUS), UAV-Medium Range (UAV-MR), UAV-Short Range, Vertical Takeoff and Landing Tactical UAV, Wasp.

Drone Aircraft and Surface Craft Testing

Testing has been conducted on the following: AQM-37, BQM-34, BQM-74, BQM-126, BQM-145, High-Speed Maneuverable Seaborne Target (HSMST), KD-2R5, MA-31, MST, QF-4, QF-86, QST-35, Vandal.

UxS Sea Range Testing

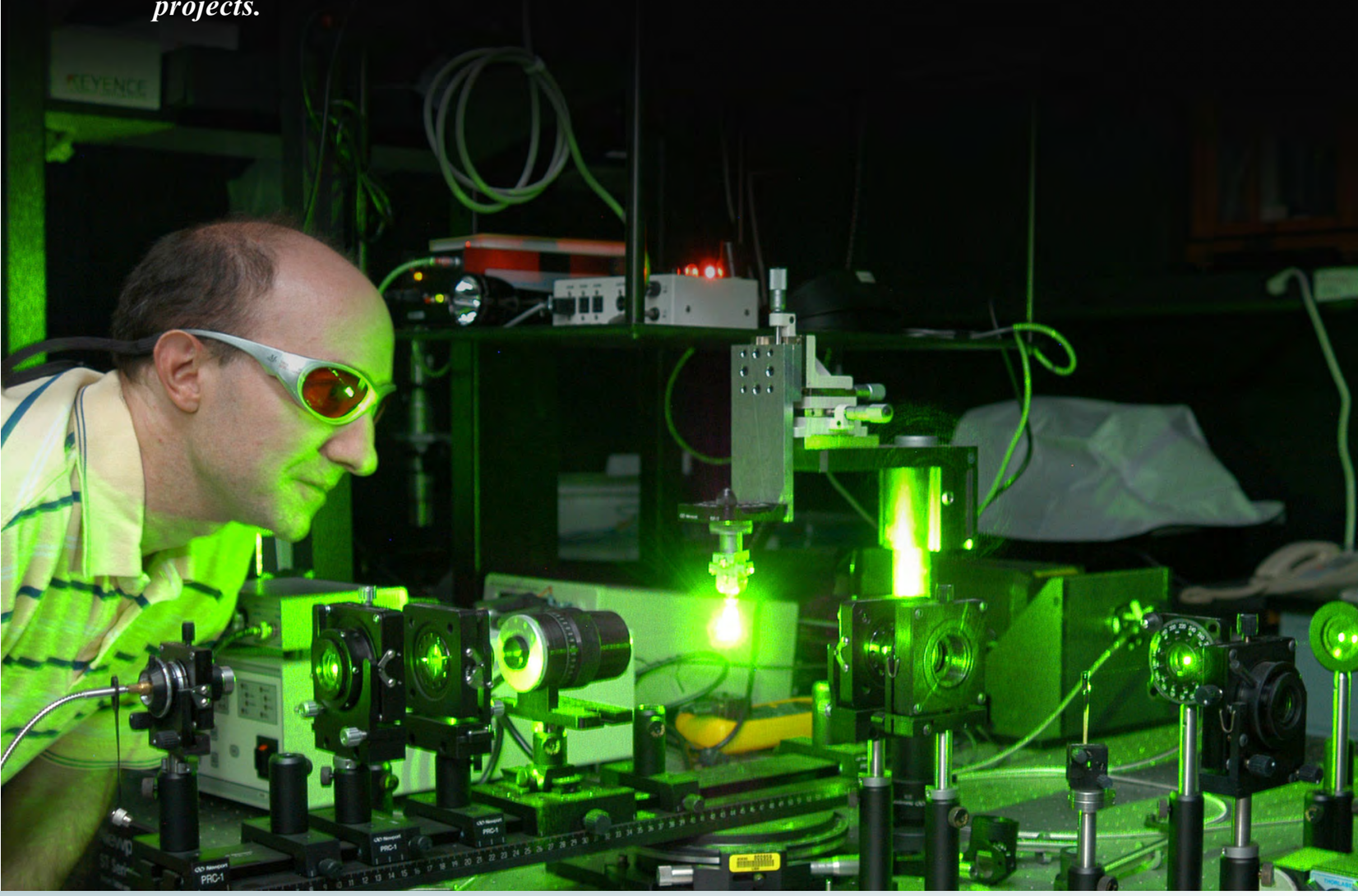
A wide variety of UxS have been tested on the Sea Range, including ScanEagle flights supporting the Collaborative On-Line Reconnaissance Provider Operationally Responsive Attack Link (CORPORAL) Joint Capability Technology Demonstration (JCTD); the Broad Area Maritime Surveillance–Demonstrator (BAMS-D); RQ-8A ship testing—MQ-8B Fleet Operational Site (2013); Raven Acceptance Test Plan and Fleet Demonstration; AeroVironment fleet of vehicles (Puma, Switchblade, Wasp); and the Predator fleet exercise.



> If there is to be another war, the shape of it will be visualized here at China Lake. Each time I come here, I have an impression that I am being given a look into the future. Here, many of the weapons of the next war will have taken shape first in the minds of some of you now present.
>
> *—John Nicholas Brown*
> *Assistant Secretary of the Navy*

Research and Engineering

Throughout its history of excellence, NAWCWD has maintained a strong research, science, and technology base. These efforts are at the forefront of new weapons and systems development that give the Warfighter a decisive advantage. Extensive research is conducted annually in a wide range of topics, including combustion sciences, firefighting, IM, energetic materials, ordnance and propulsion, and laser and optical components. NAWCWD often partners with other national and international government research agencies, such as the Defense Advanced Research Projects Agency (DARPA), Office of Naval Research (ONR), NASA, and NATO. NAWCWD also often partners with private industry in joint research projects.



Research and Engineering

Biology

Aircrew Physiological Studies
Point Mugu developed techniques for obtaining in-flight physiological data, especially in the multi-stress environment of flying tactical jets. In the late 1950s, research was conducted to design and build an instrument that would monitor and record in-flight aircrew electrocardiogram, respiration, and pulse rates. In the late 1960s, the Navy developed an in-flight recorder bio-pack for monitoring such bodily functions. This device transitioned to the In-Flight Physiologic Data Acquisition System (IFPDAS), which is used at Point Mugu to monitor aircrew flying the A-4, F-4, and F-14 aircraft. By the late 1970s, Point Mugu engineers made further advancements to the IFPDAS III. This knowledge was used to develop specifications for future life-support systems.

Biomimetics
In 2008, as part of a new biomimetic technology initiative, NAWCWD China Lake released a study conducted in association with the University of Wyoming on the eyes of flies and other insects. The common fly has an amazing ability to find moving targets in cluttered backgrounds, as well as land on moving "platforms." Researchers wanted to know how flies accomplish these tasks effortlessly and then possibly apply this research to improve imaging sensors and signal processing. From this research, a fiber-optic sensor was developed.

Chemistry

Advanced Oxidation Technologies (AOTs)
AOTs refer to a group of chemical and physical processes that can be used for air or water treatment and purification. Current laboratory work being performed at China Lake focuses on improved semiconductor catalyst applications. Semiconductor materials have been synthesized, characterized, and tested and are validated against industry standard materials. Testing is also done to determine the applicability of the photocatalytic process for the treatment of other types of contaminated wastewater. It is envisioned that improvements in photocatalysts, when coupled with technologically advanced reactor systems, will reduce water-processing costs significantly, while greatly minimizing waste production and disposal.

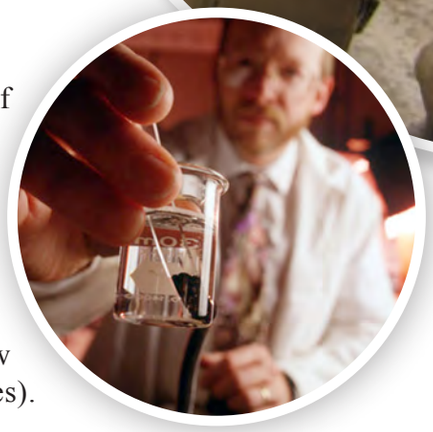
Chemical/Biological Agent Defeat Program
China Lake is currently studying ways to defeat chemical and biological weapons. In association with the Defense Threat Reduction Agency (DTRA), these studies focus on three different energetic materials—enhanced thermites, solid interhalogenate salts, and difluoramine explosives. The goal is to create explosive fills that, upon detonation, generate species that kill biological weapons and break down chemical weapons. In tests against simulated biological weapons, spores were killed after only 20 minutes of exposure.

Clean-Power Generator
Scientists at China Lake are researching new ways to bring clean power to off-grid targets, radars, repeaters, and radios on the test ranges, as well as, on a larger scope, helping to save the earth's limited supply of fossil fuels. Using an experimental hydrogen fuel cell concept, engineers are testing a prototype that can turn the sun's energy, collected through solar panels, directly into voltage without batteries. Currently, the ranges use solar photovoltaic panels to collect and store energy in large banks of batteries, which run the repeaters and other range operations.

Corrosion Prevention
NAWCWD has sought to replace the toxic heavy metals cadmium and hexavalent chromium with environmentally friendly electro-active polymers in coating systems on aluminum and high-strength steel parts for marine aircraft. NAWCWD researchers have performed pilot-scale synthesis, coated test panels, and tested coating system performance as part of joint efforts with the Army, Navy, Air Force, and multiple universities to see if the new materials can replace the toxic ingredients in aircraft coating formulations.

Full-Spectrum Ballistic Eye Protection
In 2009, NAWCWD demonstrated a new material that improved contrast ratio and switching speeds in full-spectrum ballistic eye protection. The clear state allows for more than 85% light transmission, while the dark state transmits less than 20%. This material can also clear from 30 to 80% in less than 1 second and darken from 85 to 50% in 3 seconds. Only minimal power is required to darken the lens. No power is required to keep the lens dark, and it can stay dark for weeks. The current produced when the lens is cleared is proportional to the level of darkening.

High-Temperature Composites
NAWCWD developed new breakthroughs for a new class of materials to be used in weapons and aircraft that operate in the marine environment. These new resins are capable of surviving for short periods at temperatures in excess of 700°F. For example, some can withstand the heat from a blowtorch. A major milestone was achieved in 2005, when NAWCWD researchers created the world's first carbon-fiber-reinforced composite article made from these new materials (high-purity arylethynyl-terminated polyphenylenes).



Liquid Bipropellant

Controllable thrust-on-demand propulsion systems are required for numerous military and space applications, including axial propulsion for propelling a payload, propulsive vehicle steerage (known as divert), and propulsive vehicle pointing (known as attitude control). These systems must be versatile enough to provide the exact amount of thrust required for a specific mission with precision timing. Thrust on demand must be provided in multiple directions to intercept high-speed threat payloads, and propulsion systems must be packaged in a small volume with minimal weight.

Molecular Photonic Materials (MORPHs)

China Lake continues to participate in the DARPA MORPH Program. The program's emphasis is to build a low-voltage high-bandwidth optical modulator and sensor-protection devices. Films and devices of revolutionary new nonlinear optic (NLO) materials are prepared in laboratories at Lumera Corporation, the University of Washington, and the Georgia Institute of Technology. Scientists at China Lake, the Air Force, Army, Naval Research Laboratory, and the Laboratory for Physical Science (University of Maryland campus) form the team for modeling, testing, and evaluating the NLO organic materials. Films in devices tested in government laboratories have achieved record-setting electrooptic coefficients.

Nanoscale Metal Powders and Reactive Composites

Metal fuels, like aluminum and magnesium, are used in many propellants, flares, countermeasures, and explosives. One area of intense research at NAWCWD is nanoscale metals and composites. Nanoscale materials are roughly one billionth of a meter in size. In the mid-1990s, NAWCWD scientists found that fine-grain (150-nanometer) metal powders developed in Russia were capable of enhancing detonation velocities in explosive and increasing propellant burning rates two- or threefold. NAWCWD developed and patented a new solution method for preparing fine-grain aluminum powders (50 to 500 nanometers). In collaboration with Los Alamos National Laboratory (LANL), NAWCWD also patented lead-free percussion primer mixes based on metastable interstitial composite technology—nanoscale composite mixtures of an ultrafine metal fuel and an oxidizer. These primer mixes could replace conventional ammunition primers that use either lead azide or lead styphnate, two toxic materials that cause neurological, gastrointestinal, reproductive, and renal damage in humans.

Navy P3 Resin

In 2009, NAWCWD successfully produced a P3 polymer with a phenylethynyl end cap (Navy P3 resin) using a controlled temperature scale-up for the first time. The batch weighed

more than 1 pound and will allow composite test panels and cylinders to be manufactured for evaluation at China Lake. The resin offers significant gains in affordability, moisture resistance, and safety during fires compared to current resins.

Nonlinear Optical Polymers (NLOPs) for Precision Navigation/Data Transmission
Chemists at NAWCWD have developed several NLOPs that offer lower cost and higher performance in fiber-optic, avionic, and photonic applications. For example, these polymers will become part of a revolutionary new guidance capability that will allow troops to stand off at great distances and take out enemy targets with pinpoint accuracy.

Optical Dome Material Work
Since the first IR-guided Sidewinder missile flew in the 1950s, NAWCWD China Lake has developed domes with improved durability to protect seekers' delicate optics. IR domes must survive high-speed collisions with rain, sand particles, and bugs.

In the 1980s, China Lake also marshaled leading laboratories in academia and industry to identify new, durable materials for long-wave (8- to 12-micrometer wavelength) seekers. Out of this effort, by 1990, chemical-vapor-deposited diamond was identified as the most promising material. In a decade-long effort, diamond was taken from a microscopically thin laboratory curiosity to millimeter-thick, centimeter-size windows capable of being tested on rocket sleds. Today, NAWCWD China Lake is exploring new frontiers in developing window materials with nanometer-size grains that might possess increased strength and ability to form complex shapes, thereby opening up the possibility of fabricating tough composite windows.

Unitary Fuze Module
In 2005, NAWCWD researchers applied for a patent for a new unitary fuze module with its own onboard sensors that monitor the environmental conditions and arm the weapon when the required conditions are met. These conditions may be at a safe separation distance from the launch platform or at a decreasing distance to the target. Personnel can easily install the self-contained fuze module with only one bus connection to the launch platform on ordnance such as JDAM. Having onboard sensors results in more-reliable arming. This capability is especially important because unexploded ordnance is used by insurgents to create IEDs.

Very-Low-Absorption Coatings
China Lake researchers are working with the Air Force to improve window materials, coatings, substrates, and optical metrology that will improve the performance of beam and fire-control optics on the Airborne Laser. These new technologies will have direct applications for heat-seeking missiles, surveillance and tracking systems, and high-power lasers. Improved antireflection coatings will also increase standoff distances, enhance resolution and target recognition, and provide better discrimination of decoys, as well as mitigate sea-surface glint and reduce power requirements for future versions of weapon systems, including the Advanced Targeting Forward-Looking Infrared (ATFLIR) pod, Standard Missile, and Sidewinder.

Computer Technology

Bomb Mission Planning Tool
NAWCWD developed a graphical user's interface (GUI) for the naval stores planning and weaponeering component of the Joint Munitions Planning System. Fleet support turned the GUI development into a stand-alone program. NAWCWD enhancements evolved from interactions with warfighters and expertise in weapons systems. NAWCWD integrated Joint Munitions Effectiveness Manual hard-target penetration tools into a Paveway Munitions Planning Tool (PMPT), thus providing a "one-stop" tool for LGB mission planning.

Early Computer Technology
In 1946, the world's first fully electronic computer, the Electronic Numerical Integrator and Calculator (ENIAC), began operation at the University of Pennsylvania. In 1950, China Lake was eager to adapt the new machines to its needs. Two China Lake chemists designed and constructed an analog computer that was made of old radar and radio parts. The computer dramatically reduced the time necessary to calculate the theoretical performance characteristics of certain propellant compositions.

In the early 1950s, Point Mugu had one of the first large digital computers ever built, the Raytheon Digital Automatic Computer (RAYDAC), which was used as the nucleus of a real-time telemetry data reduction system. RAYDAC consisted of a large number of vacuum tubes and banks of mercury-filled acoustic delay lines.

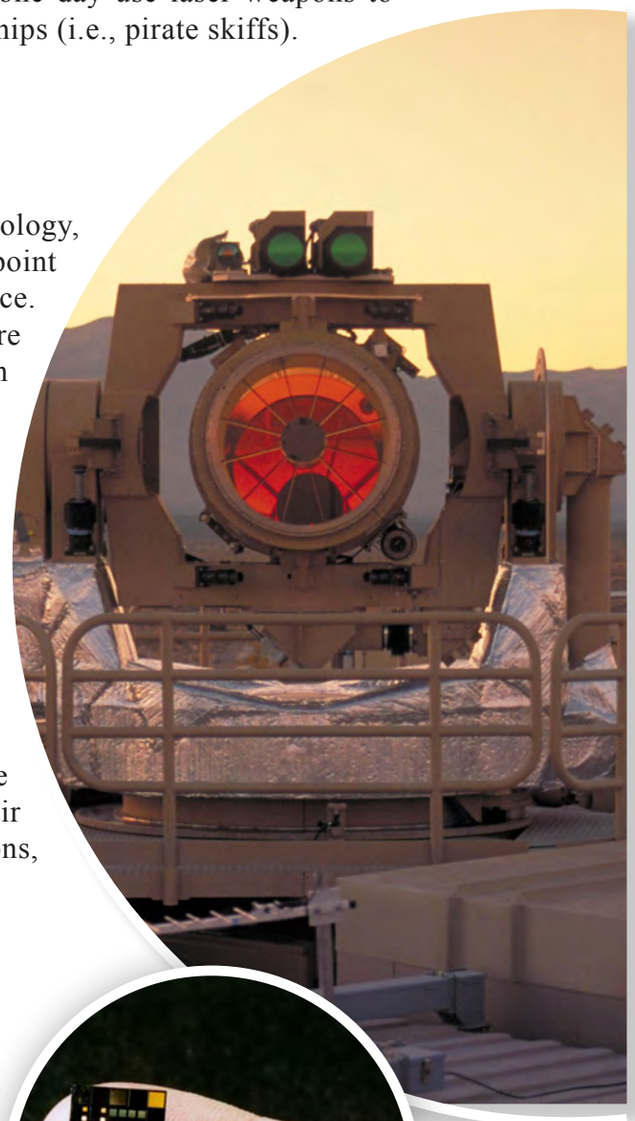
The Technical Library at China Lake also developed a computer system in the 1950s that could search a database by subject. The IBM 701, the first mass-produced computer and defense calculator, is credited with conducting "the first subject search ever made by a digital computer" in 1954.

Level Set Geo-Registration Image Enhancement
Using a mathematical theory known as level sets (best analogy is a topographic contour map), China Lake researchers, in association with Cognitech, developed a tool that automatically registers video or still frames from tactical sensors to a Digital Point Positioning Database or other controlled reference image base. Using level sets and registration, Navy personnel can perform a variety of image enhancements. Level set geo-registration allows for frame fusion and integration, thereby clearing up distortion in the video frames.

Directed Energy Weapons (DEWs)
DEWs are large concentrated doses of energy (i.e., photons or particles traveling at or near the speed of light) directed toward targets to destroy them. China Lake is currently conducting research and development of high-energy laser (HEL) technology, including using fiber lasers, laser architecture support beam control, microwave radiation emitters, electromagnetic rail guns, particle beam accelerators, and diode pumps. Laser weapon projects tested at China Lake included the Laser Avenger, which is a High-Mobility Multipurpose Wheeled Vehicle (HMMWV)-mounted directed energy air defense system. During a 2009 test, the Laser Avenger shot down six drone

aircraft over the Land Ranges. In 2010, a laser weapon system successfully tracked, engaged, and destroyed a drone in flight during a test at San Nicholas Island on the Sea Range. This test was significant and illustrated the potential lasers can provide to the U.S. military. Typically, a laser loses effectiveness as it moves through a moist, salty sea air, but, as the DEW demonstrated, it did not lose power and was accurate. The Navy expects to one day use laser weapons to intercept antiship missiles and other threats, including smaller ships (i.e., pirate skiffs).

Electronics



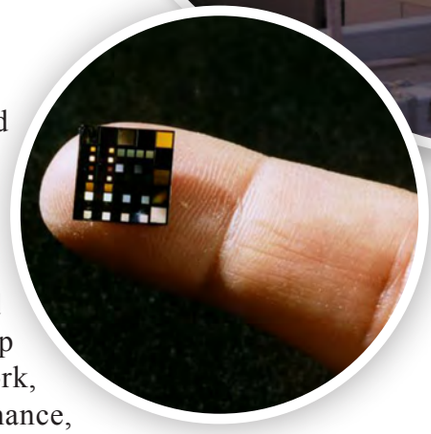
Microelectromechanical Systems (MEMS)

Miniaturization technologies, such as MEMS and nanotechnology, are the future, and NAWCWD continues to develop multi-point initiation for an electromagnetically actuated MEMS device. High-speed digital video cameras were placed to capture the timing between the detonations. Post-shot inspection indicated that all micro-explosives detonated, as evidenced by dents and hole expansion. Extensive testing with MEMS contributes to the production of micromachines, micro-integrated circuits, and microoptics that will be used in the defense, security, and aerospace sections.

Super-Capacitor Technology

NAWCWD researchers work with private industry and academia to develop super-capacitors that will demonstrate 80% charge storage retention after 100,000 cycles at 75% depth of discharge. This project will significantly reduce the size and weight requirements for power supplies for air weaponry, UAVs, and portable electronic devices for weapons, communications, computing, surveillance, and sensing.

Energetics



CL-20

In 1987, researchers at NAWCWD China Lake invented CL-20, a breakthrough in energetic materials, a compound with a higher energy density and lower sensitivity than those of previous materials. CL-20 has been called the "most significant energetic ingredient in 50 years" because of its high performance, minimum signature, and hazard characteristics. The synthesis process for CL-20 was scaled up by industry to produce sufficient material for formulation work, and the formulations have been characterized for performance, signature, and safety properties. CL-20 also has important applications in the commercial world. A Cooperative Research and Development Agreement (CRADA)

was established with Thiokol Propulsion to perfect the material for scale-up to commercial production and availability for military and commercial applications.

Improved Combustion in Thermobaric Explosive Formulations

In 2005, three new patents were issued to NAWCWD researchers for creating thermobaric explosives with improved combustion efficiency. Thermobaric explosives work by first expelling a cloud of explosive mist using a small charge and then igniting it with a second charge. While effective in open spaces, these types of bombs have proved ineffective in confined poor-oxygen environment areas, such as in tunnels. The new explosive components have a 50 to 100% higher blast energy and will help to eliminate these problems.

Insensitive Munitions Technology Transition Program (IMTTP) Warhead Demonstration

In 2004-2005, IMTTP efforts greatly improved the IM performance of a 5-inch-diameter warhead when compared with the existing Sidewinder warhead. This capability was demonstrated by utilizing both a directional-based initiation design and the conventional end-initiated design currently used. Working with the Joint Navy/Air Force IM Bomb Program, NAWCWD designed new annular bomb fills with shock-attenuating liners to mitigate sympathetic detonation in general purpose bombs.

Integrated High Payoff Rocket Propulsion Technology (IHPRPT) Program

Meeting the demand for future Navy missiles requires continuous technology development. The IHPRPT Program, started in 1994, is an integrated tri-service/NASA/industry effort to develop and demonstrate innovative, revolutionary technologies that will double rocket propulsion capabilities, including boost, space, and tactical. NAWCWD handles 80% of the tactical IHPRPT Program, leads the tactical demonstrator program, and bears overall responsibility for propellants and control systems.

In 2005 and 2006, NAWCWD completed payoff studies involving the AIM-9X, AMRAAM, and RAM, and results showed significant improvements in increasing propellant energy and motor volumetric loading, decreasing component weight and volume, and increasing component efficiency, without sacrificing safety or increasing cost.

Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS)

Fire is a leading contributor to attrition of aircraft in combat. Active fire-suppression systems, however, can often be complex, costly, and heavy. Various passive fire-protection technologies exist that are low cost and low weight. For example, the simple passive extinguisher involves a reactive agent placed or installed directly within the aircraft compartment. Fire activates the agent, which rapidly fills the compartment and extinguishes the fire. In addition, upon ballistic impact, reactive powder panels will break open and release the encased fire suppressant powder. The JTCG/AS project at China Lake is investigating the use of an energetic material to enhance powder release from such panels. For example, ionomer fuel containment technology could be used to produce better self-sealing materials, hot surface ignition mitigation to reduce the surface-to-liquid heat transfer when flammable fuels encounter hot components, and intumescent firewalls that respond to fire by swelling several orders of magnitude beyond their original thickness to thermally protect and insulate the structure.

NAVSEA/NAVAIR Navy Energetics Program

The power of energetic materials is a critical Navy technology, ranging from a 5-milligram low-energy initiator to an 81,000-pound rocket motor. In every Navy weapon, this material either burns or blows up. Because Sailors live at sea in close quarters with high-explosive weapons, munitions are an even greater concern to the Navy than for other military branches. The Navy Energetics Leadership Board (NELB) and the Navy's Energetics Integrated Product Team (EIPT) are forging a unified NAVSEA/NAVAIR energetics program that represents all four of the Navy's energetics laboratories: Crane, Indiana; Dahlgren, Virginia; the Indian Head Division of the Naval Surface Warfare Center, Maryland; and NAWCWD at China Lake and Point Mugu. The NELB will "preserve the Navy's competency in energetics, foster collaboration among warfare centers, and speak for the Navy energetics [community] with a single voice."

Reduced-Smoke Propellant

At the end of World War II, solid rocket motors were made from the same smokeless double-base propellant (i.e., nitroglycerine and nitrocellulose) used in guns. More-modern rocket motors, however, use propellants composed of rubber binders filled with powdered ammonium perchlorate and solids like powdered aluminum. This composition performs better than previous propellants and can be cast into motors of any size and shape but produces a white smoke that, in certain weapon systems, is extremely disadvantageous. In response to the needs of the Sidewinder and the HARM teams, during the 1960s, China Lake engineers developed a composite propellant without the aluminum powder. This became known as a reduced-smoke propellant. Removing the aluminum caused only a slight reduction in performance but did introduce the problem of combustion instability. China Lake soon solved this problem by developing reduced-smoke motors for Sidewinder and HARM in the 1980s.

Roseville–Benson Investigations

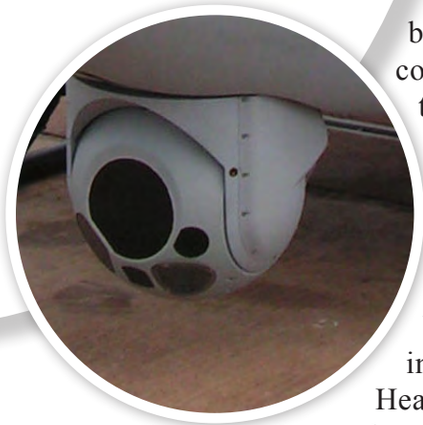
In 1973, explosions rocked two different trains carrying Air Force bombs filled with Navy-developed explosives. The incidents, one at Roseville, California, and the other at Benson, Arizona, shook public confidence in the safety of transporting military ordnance and resulted

in a lawsuit against the government. China Lake explosives experts conducted a rigorous examination of the entire process of the design, manufacture, and quality control for the Mk 81 and Mk 82 bombs involved and solidly demonstrated the safety of the weapons. Through careful scientific investigation of the explosion sites and laboratory analysis of the evidence, the China Lake team isolated the cause of the disasters to the trains' faulty brake shoes that set fire to the wooden boxcars carrying the bombs. Over a period of 7 years, China Lake scientists and engineers assisted U.S. attorneys in developing the technical aspects of a defense that saved the government between $50 and $90 million in damages.

High-Speed Weapons (HSWs)

High-speed supersonic and hypersonic weapons can provide dramatic improvements in platform and weapons survivability, in the ability to engage time-critical targets, and in the penetration of hardened and deeply buried targets. NAWCWD's strategic objective is to position itself as the leader in HSW development, thus giving the United States a definite decisive advantage.

NAWCWD has conducted extensive work in the technologies required to make such weapons a reality, including efforts in advanced airbreathing propulsion systems (i.e., ramjet), blended body airframes, high-temperature materials, and ordnance package concepts. Programs such as RATTLRS are under way to demonstrate these technologies in flight testing.



Increased Capabilities Against Moving and Stationary Targets

NAWCWD is currently developing two systems to increase the Navy's capability to engage moving and stationary surface targets in all weather conditions. The first system is the Direct Attack Seeker Head (DASH), a low-cost dual-mode (imaging IR/millimeter wave) seeker for attacking moving and stationary surface targets in adverse weather conditions. DASH's goal is to provide that much needed capability to the Tactical Tomahawk, but the modular seeker design will allow integration into a variety of weapons by using adapter kits.

The second system is the multimode sensor seeker, which utilizes visible, IR, and laser radar sensors in correlation with advanced automatic target recognition algorithms to increase target identification in all-weather maritime environments and reduce false alarm rates and operator workload. The sensor hierarchy will also provide increased standoff range. This system is intended for the MQ-8 Fire Scout but may also be placed into future weapon systems.

Missile Airframe Technology

NAWCWD missile airframe technology efforts provide affordable airframe structures, stable weapon flight, increased maneuverability, safe separation from launch platforms, reduced drag, improved aero-prediction and defense penetration techniques, and high-temperature airframes.

NAWCWD has greatly advanced composite material technology and was instrumental in developing American Society for Testing and Materials standard material test methods that are now used by the industrial community for characterizing the structural performance of filament-wound composite structures. Before this time, there was no accepted method to qualify manufacturers. NAWCWD is developing the advanced high-performance motor cases needed to satisfy IM requirements and the lightweight high-temperature structures required for high-performance hypersonic weapon systems.

Physics

Nanoplasmonics and Metamaterials

The need for miniaturization of optoelectronic components is critical for reducing the footprint and weight of future weapons systems. Currently, most optical devices are built at the scale much larger than the wavelength due to the limitation of wave diffraction that prohibits light transmission in the sub-wavelength scale. The latest developments in nanoplasmonics and metamaterials offer the potential to overcome this diffraction limit, thus enabling devices to be built in the sub-wavelength scale. Another newly discovered application of these materials is a novel physical effect of the nonlinear properties of metamaterials. Nonlinear metamaterials can shield objects from high-power laser beams. It has been observed that the shielding strength increases with increasing laser power.

Radiant Virgo and the Moving Target Demonstration

Under the Radiant Virgo project, researchers developed an application that provides automated geo-registration of tactical UAS video obtained from electrooptic and IR sensors. With the use of a Digital Point Positioning Database to help derive precise coordinates, PGMs can then engage relocatable, nonmoving ground targets in nearly real time. Virgo was also adapted to utilize other nongovernmental resources, including WorldView1.

The moving target demonstration builds on the geo-registration capabilities of Radiant Virgo by incorporating a moving tracker. This modification will provide PGMs with moving target track capability for passive moving target tracking and precision engagement on the ground. The goal is to automatically track objects of interest and provide automatic geo-rectified updates at 1/2- to 1/5-second intervals.

Technology Transfers

NAWCWD transfer programs have included telecommunications on radar systems, video frequency data conversions, data displays, test facilities, and a design for an airport firefighting system for short takeoff and landing airports for the FAA. Work was done in low-light-level television, voice scramblers, patrol car tracking, and personnel communication links for the Law

Enforcement Assistance Administration. Biomedical ideas have been brought to life for the National Institute of Health, and an air quality control monitoring program conducted mapping of aerosols for the State of California. Other significant NAWCWD contributions resulted from investigations into wind, solar, and geothermal energy; solid waste conversion to clean-burning fuel; aircraft survivability; and an explosive device used to clear fire lines for the Forest Service. It would require volumes of documents to describe all the research and technology that NAWCWD has transferred to industry. The following subsections, though, highlight many of these achievements.

Actuated Cable Cutters

In the early 1950s, China Lake developed a blank explosive cartridge-actuated cable cutter for emergency cable cutting for ship tow/transfer lines, helicopter supply lines, etc. In 1990, this technology was transferred to private industry, and, today, several companies have developed advanced cartridge-actuated cutting tools that are used nationwide, as well as by many countries throughout the world for police, sheriffs, special weapons and tactics (SWAT) teams, and fire departments to cut security bars, chains, and locks.

Calcification-Prevention Tablets

For decades, the Navy dealt with the problem of calcium buildup in the sewer systems aboard ships. When urinals are flushed with sea water (which is well saturated with calcium), uric acid and other acid components cause precipitation of calcium carbonate, which builds up on the inside of the ship's plumbing. The traditional cure for pipes clogged by calcium deposits is hydroblasting, which is expensive and time-consuming. NAWCWD China Lake scientists developed inexpensive, environmentally friendly water-soluble polymers that are placed into urinals in tablet form and release citric acid to bind the calcium in the flush water. Today, virtually every ship in the U.S. Navy carries and uses this product. This technology is also being used by industry in countless commercial vessels and facilities worldwide.

Chemiluminescent Light Stick

NAWCWD China Lake developed the chemiluminescent light stick technology between 1962 and 1986 for military use as emergency lighting for life rafts, downed flyer beacons, map reading, and damage evaluation. An improved technology was patented in 1986 and 1987, and it was licensed commercially. Commercial uses include novelty items and safety illumination sticks for emergency kits and commercial fishing lures, as well as brightly glowing novelty safety necklaces. This technology also received the 1993 Federal Laboratory Consortium (FLC) Award for Technology Transfer Excellence.

Chlorofluorocarbon (CFC) Elimination for Soldering and Fire-Suppression Applications

NAWCWD China Lake evaluated commercially available non-ozone-depleting products for cleaning electronic assemblies and helped to develop and test low-residue no-clean solders, citric-acid-based flux, and wave soldering processes. With military aircraft susceptible to fires caused by ballistic penetration of fuel tanks, Halon 1301 was the agent of choice for extinguishing fires. It, unfortunately, was also being phased out. In response, NAWCWD developed gas generators ("pyrotechnic extinguishers") that produced large quantities of inert gases to smother fires. The first patent for this technology was issued in 1986.

Continuous Emissions Monitor (CEM)

The TraceAIR™ system was developed to answer an environmental need to monitor pollution from the primary 14 toxic airborne metals frequently emitted from incinerator stacks. A CRADA between NAWCWD China Lake and Thermo Jarrell Ash Corporation was formed, and the system was developed, tested, and validated as a viable commercial environmental monitor. In 1997, the TraceAIR™ CEM system was recognized as a winner of one of the prestigious *R&D Magazine* 100 Awards. These awards recognize the 100 most technologically significant new products of the year and have been referred to as the "Oscars of Invention" and the "Nobel Prize of Applied Research." The inventors of the TraceAIR™ system were also awarded a 1998 Award for Excellence in Technology Transfer by the FLC.

Diamondoids

In 2004, NAWCWD negotiated a CRADA with Chevron to jointly develop new products based on "diamondoids," which are nano-diamond fragments that are very rigid and stable. ChevronTexaco recovers diamondoids from natural gas wells. NAWCWD is exploring potential uses as building blocks for optical and structural components of future weapon systems. Decades ago, similar compounds were investigated for airbreathing rocket fuel at China Lake, but new purification methods are making a wide variety of new structures available for other applications.

Dual Polarized Broadband Tapered Slot Antenna

NAWCWD researchers invented a low-cost, lightweight dual polarized broadband tapered slot antenna that can be used for multiple applications and is very cheap to manufacture (e.g., $200 versus the $5,000 charged by contractors). The first and second radiating antennas are colocated and positioned to be perpendicular to one another. Each antenna includes a relatively thin dielectric substrate and a radiating metallic antenna element mounted on the upper surface. These new antennas allow for linear, elliptical, and circular polarization.

Electrical Initiation System

Electrically ignitable primers have been previously used in military applications for high-speed firing of various-sized-caliber ordnance; in blasting for mining operations; for automotive crash bag initiation and inflation; and for seismic guns, kiln guns, rocket motors, and pyrotechnic displays. Many of these primers, however, are not suitable for small arms such as rifles, pistols, and shotguns. Typically, electrically ignitable primers initiated by exploding

bridgewires or hot wires in combination with a semiconductive mixture, pyrotechnic mix, or conductive mix suffer from relatively long ignition times. This new electrical initiation technique relies substantially on vaporizing a thin metallic film or strip and rapidly igniting a lead-free explosive composition. The patent on this technology was awarded in 2005.

Environmentally Friendly Mixture of Trinitrotoluene (TNT)
NAWCWD researchers were issued a patent in 2005 for making an environmentally friendly explosive mixture of TNT by using a cyclodehydrative condensation mechanism for melting the high explosive. This method does not produce unwanted highly toxic nitration isomers that must be discarded, a very expensive process. The new materials generated can be safely reused.

Exploding Foil Initiator (EFI) Based Squib Arm-and-Fire Device (AFD)
During the Bosnian conflict, China Lake developed the low-energy exploding foil initiator (LEEFI), which is used in-line with main charge explosives to safely initiate warheads. The LEEFI employs microelectronics technologies that required only half as much energy as conventional initiators, and production was two-thirds less labor intensive. In 2004, EFI technology advanced and has significantly reduced the cost and weight of rocket motor safety devices. Other applications include use in thermal batteries, non-detonating self-destruct mechanisms, and pyrotechnic ignition devices.

Explosive Forming and Welding
During the 1960s, NAWCWD China Lake invented explosive forming and explosive welding, two exotic techniques that revolutionized metal fabrication. In the course of investigating terminal ballistics, shaped charges, and metal-explosive systems, China Lake scientists discovered that a small explosive charge is capable of exerting tremendous forces on a piece of metal by generating shock waves through a medium (usually water or oil), which can then be directed to deform a workpiece at very high velocities. In a second method, an explosive charge is held in direct contact with the workpiece while the detonation is initiated, thus producing interface pressures on the surface of the metal up to several million pounds per square inch. The shock waves perform the same function as a mechanical punch. Today, the techniques pioneered by NAWCWD China Lake are widely used in the aerospace and aircraft industries, as well as in the production of automotive components.

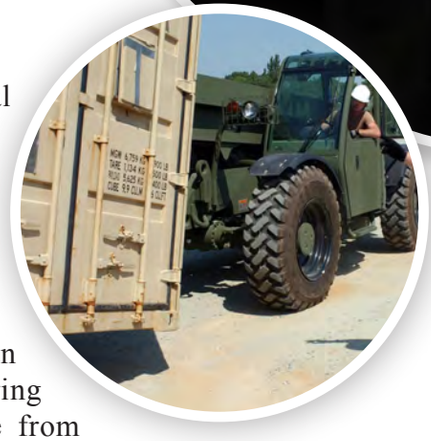
Geophysical Warfare, "Rainmaking"
During the Vietnam conflict, the United States military needed a way to interdict enemy traffic on the Ho Chi Minh Trail. NAWCWD China Lake developed weather manipulation technology to "seed" specific clouds to enhance rainfall, thereby significantly deterring enemy activity on the trail. NAWCWD personnel participated in Operation Popeye, a top secret project (now declassified) to train B-52 pilots to use C-130s to seed certain clouds. This project was highly successful, and the Ho Chi Minh Trail was washed out, thus making it impossible for the enemy to move to their destinations. This project was the first time the military manipulated the weather as a weapon. This highly successful technology is used today by industry in hurricane abatement, fog control, and drought relief.

Geothermal Energy
In 1964, geological engineers at China Lake discovered the enormous geothermal potential on the northwest portion of the base. In 1977, a Navy plan was developed for a private industry contract. The intent was to take advantage of the geothermal energy to generate savings to the Navy for the cost of electricity and to stimulate the Navy's alternative energy program, thereby allowing the Navy to become more independent of foreign fuels. A contract was awarded to California Energy Company, Inc.

Total savings to NAWCWD since that time exceed $36 million, and the Navy will save in excess of $500 million during the life of the contract.

The military set a goal that 25% of its energy should come from renewable sources by 2025, and NAWCWD China Lake was assigned the lead role for all Navy geothermal efforts, even those not geographically limited to China Lake. As environmental concerns continue to shift toward "greener" power sources worldwide, geothermal technology will stay in the forefront to supply energy by using the earth's inner heat.

Hazardous Materials (HAZMAT) Containers
NAWCWD Point Mugu was involved in helping develop new technologies for HAZMAT containers. These containers help the Navy comply with strict Resource Conservation and Recovery Act regulations, as well as provide the Navy with a significant cost savings. During the first year of operation, for example, the Navy reduced its HAZMAT purchases from $132,000 to $55,000, with only one directorate participating in the program. The second year, purchases dropped to $43,000. More than 60 different types of HAZMAT containers are currently in use at Navy/Army/Air Force facilities around the world. They are also currently available on commercial carriers.



Health Monitoring System for Warfighters
NAWCWD researchers, in conjunction with Sun Biomedical Technologies (SunBMT), have developed novel data mining techniques for the early detection of disease. This new capability has the benefit of increasing both warfighter productivity and mission success rates. Warfighter productivity decreases during the symptomatic stage of any illness. Early detection, along with proper medical care, greatly reduces the duration of the illness. Also, missions can be compromised if critical personnel are noticeably ill during the mission. The gestation period for diseases can range from hours to years; therefore, the Warfighter may be unaware that he or she

is sick prior to deployment. Testing essential personnel for disease before deployment will reduce the number of sick warfighters in the field. The procedure created by NAWCWD and SunBMT accomplishes these goals by using a small blood sample to reliably predict disease occurrence before the onset of symptoms.

Improved Soldering Technology

During the 1970s, NAWCWD China Lake pioneered a unified set of state-of-the-art soldering techniques, materials, and processing technologies to ensure the production of high-quality, high-reliability electronic modules for military systems. China Lake also developed WS-6536, the DoD soldering specification. This effort led to a set of highly successful soldering technology seminars and training courses that were regularly presented and hosted at China Lake from 1976 to 1993. Industry sent representatives to China Lake for training and certification. In 1993, the training course was transferred to industry through a CRADA between NAWCWD and Comarco, Inc. The soldering technology and techniques developed under this program led directly to today's high-quality, high-reliability electronic systems in the commercial marketplace.

Injection Loading of Energetic Materials

NAWCWD China Lake began developing injection loading technology in the mid-1980s to meet the Navy's IM requirements. This process provided a valuable means of loading explosives into munitions, thus providing a greater range of loadable viscosities and consistent load quality. For plastic-bonded explosives, injection loading is much faster than conventional casting methods. China Lake also built a bench-scale injection loader in 1986, which was certified in 1995 for live operation. The injection loader has been in operation since and is also applicable to the propellant industry.

Lead-Free Electric Primer

NAWCWD developed and optimized a lead-free primer formulation using nano-aluminum and molybdenum trioxide, a formulation that is one of two likely candidates for integration into industry as a replacement for lead primers in electrically primed ammunition. In testing and characterization, these primers have shown very positive results and meet DoD specifications. Thus, NAWCWD's efforts have led to a safer primer with better resistance to aging.

Logarithmic Amplifiers

The first ultrasonic body scanner was pioneered at China Lake during the late 1960s and early 1970s. Logarithmic nonlinear amplifiers compress and limit the amplitude of large-dynamic-range electronic signals. At China Lake, these amplifiers were under development for radar

signal processing applications. Sonar signals can also have very large dynamic ranges. In 1971, NAWCWD China Lake transferred the design for a custom logarithmic amplifier to the Mayo Clinic, which was instrumental in the design, development, and successful demonstration of the first ultrasonic body-scanning equipment. Ultrasonic scanning equipment has since become a very important noninvasive medical diagnostic tool used worldwide.

Natural Pumice

The Ordnance Evaluation Branch at NAWCWD China Lake was the first branch of the U.S. Government to use pumice to protect assets and personnel, with three patents awarded. NAWCWD first discovered the useful effects of pumice in the late 1970s while performing sympathetic detonation research. Engineers discovered that pumice, a volcanic ash created as lava cools, is readily found on the China Lake ranges. Pumice is very accessible, easy to use, and inexpensive. It contains thin membranes with enclosed air-filled cells and is naturally effective at absorbing shock, deflecting blasts, and preventing sympathetic detonation of explosives, thus reducing explosive chain reactions. The low thermal conductivity of pumice (it melts rather than burns at temperatures around 2,500ºF) makes it an ideal fire barrier.

Toxic Metal Removal From Storm Water

In 2006, NAWCWD researchers invented and patented a method for removing toxic metals from storm water runoff to provide clean water. The treatment facility includes a pretreatment chamber for removing large toxic particles and an absorption chamber for removing fine particles of toxic metals. The absorption chamber has a bed of three absorptive materials for removing the fine particles. This invention can be easily adapted for use at any military or industrial facility.

Sensors in Automotive Air Bags

In 1994, the Navy needed a means to accurately measure the distance traveled by the missile after launch, a computation necessary for arming the warhead firing device at a safe distance from the launch aircraft. NAWCWD China Lake engineers conceived of an extremely robust and precise micro-machined miniature accelerometer. Working with a Small Business Innovative Research contractor, NAWCWD oversaw development using microelectronic fabrication techniques (to ensure ease of manufacture and lower per-unit cost) and operating with a single power supply. The device was also designed to be resistant to variations in supply voltage. The resulting accelerometer was incorporated into several warhead safe-and-arming devices (SADs). This device subsequently transitioned into millions of automobile crash-sensor air-bag-initiation systems by major foreign and domestic automobile manufacturers. The device is also used for hundreds of other consumer and industrial applications and is marketed internationally.

Stop-Action Electromechanical Shuttered Video Cameras

In 1975, China Lake test range personnel devised an invention to provide non-smeared stop-action images of high-speed video events to allow accurate position-versus-time measurements. This technology also reduced cost compared to high-speed film cameras. The method was originally developed for vidicon tube cameras, but methods to achieve the same

results with charge coupled device video cameras were also developed. A patent was awarded in 1977. During the late 1970s and the early 1980s, the technology was transferred to a commercially available multispectral video camera (a stop-action camera for sports training).

Supersonic Combustion Heating Apparatus

NAWCWD researchers were awarded a patent in 2005 for an invention that includes a sidewall cavity with an advanced mixing system with ground-based oxygen injection for hypersonic materials and engine testing. This invention enhances kinetics, produces an increased high-enthalpy flow source, enhances flame stability, improves mixing between fuel and air, and shortens chemical ignition delay, without the use of expensive film-cooled nozzles. In addition, the Navy saves an estimated $2 million for each nozzle.

Waste Incineration Technology

NAWCWD has developed and demonstrated an efficient high-temperature waste incineration technology. This technology allows smaller units to incinerate larger amounts of waste, thus using less fuel and resulting in fewer by-products than current commercial incineration processes. While investigating airbreathing (ramjet) combustion technology for aircraft and missile applications, NAWCWD researchers developed continuous computerized combustion-control technology that maximizes the heat and optimizes the location of combustion vortices within the combustor unit. This technology can be incorporated into small portable combustion units for on-site waste incineration, thus eliminating the storage and transfer costs associated with removing waste to central location.

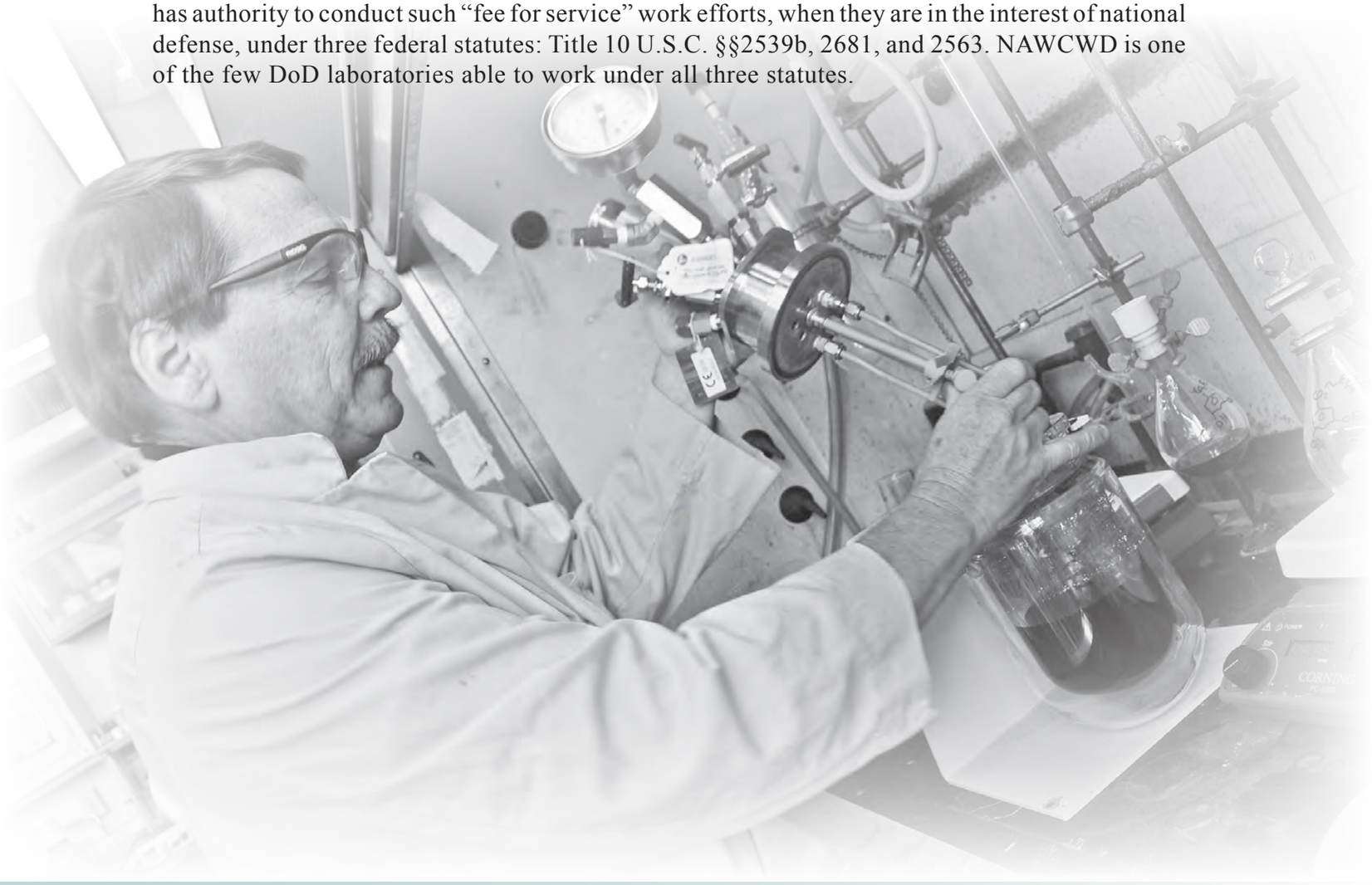
Cooperative Research and Development Agreements (CRADAs)

As our adversaries have adopted increasingly innovative tactics to disable coalition forces and impede their mission, the DoD has turned to one of its greatest assets, research and development, to counter these threats. NAWCWD has exploited CRADAs as mission extenders to leverage the capabilities of private industry in this endeavor. Several of the CRADAs recently executed in conjunction with this initiative are addressing specific force protection requirements. Through a series of CRADAs with different manufacturers, for example, NAWCWD is investigating use of lightweight armor materials to protect the occupants of HMMWVs, while preserving the vehicles' durability and off-road performance. One CRADA is investigating the feasibility of using directed energy to disable the electronic triggering mechanisms of IEDs, a technology that may also have potential for standoff detection of IED command wires. Another CRADA explores the feasibility of achieving standoff detection of sniper scopes and optical surveillance equipment.

Since the early 1990s, the number of CRADAs at NAWCWD has continued to escalate, with revenues in excess of $20 million, which represented a potential cost avoidance to the Navy of more than $66 million. Most agreements involve military-related technology; however, some CRADAs involve commercial and educational projects. For example, a CRADA with the University of California, Santa Barbara (UCSB), enables the transfer of specialized radar technology from UCSB to the Navy for the purpose of mapping ocean surface currents and wave heights in the vicinity of the Pacific Test Range. Another CRADA effort teams NAWCWD with a local medical research entity to explore the use of Navy-developed data mining and machine learning capabilities for medical diagnostic applications. Other significant CRADAs include a "TERM" ball joint seeker, integrated weapon system simulation, ESSM composite, Block IV fuze modification, guided Zuni rocket study, DPSS and Anti-Swimmer Grenade (ASG) development, counter-MANPADS research, and thermal battery research.

Commercial Service Agreements (CSAs)

CSAs are agreements in which a government laboratory conducts testing or provides services for a domestic non-Federal-government customer. Under these agreements, the customer pays the government laboratory all direct and indirect costs incurred to accomplish the work. NAWCWD has authority to conduct such "fee for service" work efforts, when they are in the interest of national defense, under three federal statutes: Title 10 U.S.C. §§2539b, 2681, and 2563. NAWCWD is one of the few DoD laboratories able to work under all three statutes.



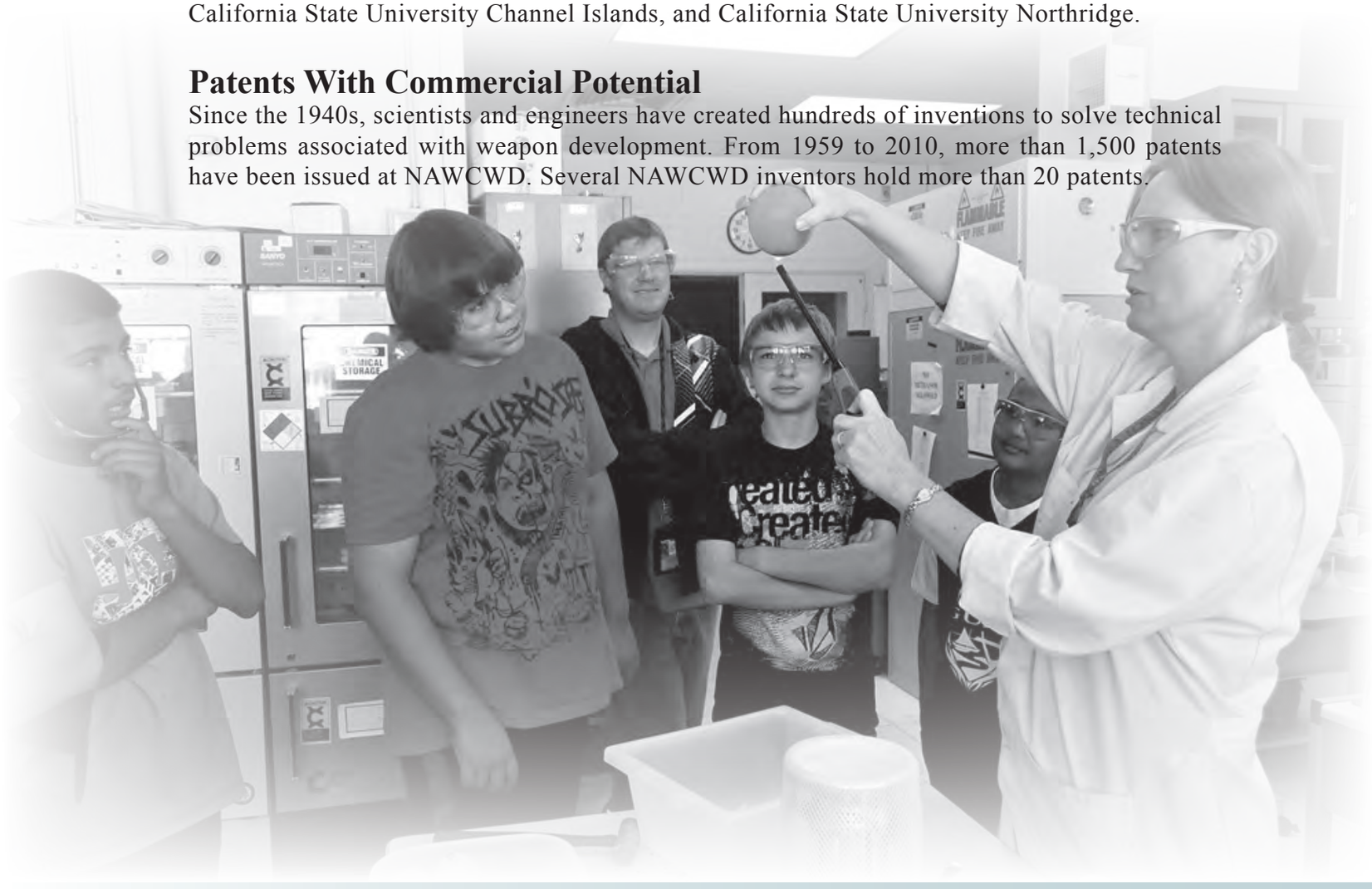
In the performance of its military mission, NAWCWD has acquired and developed specialized equipment and many one-of-a-kind facilities. With the addition of this center's dedicated scientists and engineers, the whole constitutes a significant scientific resource to industry. In fact, since the launch of NAWCWD's CSA program in 1997, the number of CSAs has climbed to more than 300, totaling more than $100 million. In fiscal year 2010 alone, 21 CSAs were enacted, with a total estimated value of $4.7 million.

Educational Partnership Agreements (EPAs)

EPAs provide a mechanism for local education agencies, colleges, universities, and nonprofit institutions dedicated to improving science, mathematics, and engineering skills to take advantage of NAWCWD staff's expertise, unique facilities, and equipment related to naval warfare systems and technologies. A primary goal of EPAs is for NAWCWD scientists and engineers to encourage and facilitate early interest in the sciences and engineering by young people at all stages of their academic careers. EPAs provide a formal vehicle for information exchange, access to state-of-the-art facilities and technology, and research experiences. NAWCWD has ongoing EPAs with Sierra Sands Unified School District and Cerro Coso Community College, which are both located in Ridgecrest, California, as well as with New Mexico Institute of Mining and Technology, California State University Channel Islands, and California State University Northridge.

Patents With Commercial Potential

Since the 1940s, scientists and engineers have created hundreds of inventions to solve technical problems associated with weapon development. From 1959 to 2010, more than 1,500 patents have been issued at NAWCWD. Several NAWCWD inventors hold more than 20 patents.



Energy Strategy

Energy Strategy

Rear Admiral Mathias W. Winter, NAWCWD Commander, released the NAWCWD energy strategy in support of Secretary of the Navy's (SECNAV's) energy vision. Central to this strategy is NAWCWD's focus on mission-compatible energy technologies, both at the installation and operational level. In addition, NAWCWD looks to partner with industry, academia, and other DoD activities to bring new energy technologies to the Warfighter. Steps being taken by NAWCWD in support of the SECNAV's energy goals include the following:

- **Implementing energy-efficient acquisition policies.** NAWCWD is answering the call by using energy-efficient products and manufacturing capabilities.

- **Sailing the "Great Green Fleet."** NAWCWD is conducting RDT&E of biofuels and advanced fuel technologies. Additionally, biomaterial technologies to replace petroleum-based plastics and materials are being developed in the laboratories. The goal is to power jet, tactical, and non-tactical assets with biofuels by 2020.

- **Reducing non-tactical petroleum use 50% by 2015.** Remote range photovoltaic power, biofuel-powered generators, and advanced energy storage systems will replace diesel generators.

- **Increasing alternative energy ashore 50% by 2020.** Advancements at the Coso geothermal power plant have resulted in the generation of 200 megawatts per year of clean energy, and solar roofs throughout the Command are decreasing electric usage dramatically. A large solar farm at China Lake is in development.

- **Increasing total alternative energy usage by 50% by 2020.** A new Mission Compatibility Analysis Tool has been produced to characterize alternative energy developments around DoD installations. "Stealth" wind technology is being researched in conjunction with industry and academic partners, and smart metering initiatives are under way. Facilities and remote operations have solar photovoltaic installations to increase alternative energy generation.

RDT&E of Energy Technologies

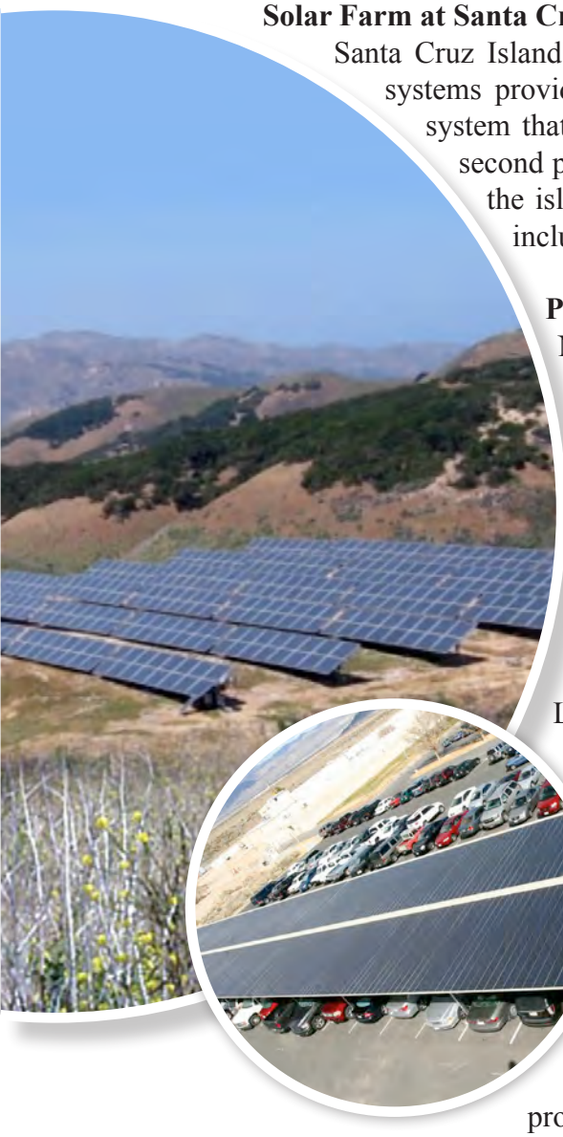
Biofuel Research

Rear Admiral Mathias W. Winter signed a CRADA with Cobalt Technologies, Inc., a Bay Area company, for the development of a Navy biofuel. Biomass waste could soon be transformed into the bio-jet fuel of choice. Research chemists at China Lake have developed proprietary processes for converting the sugar alcohol n-butanol (which is harvested from plant waste material) into jet and diesel fuel.

Renewable Energy Technologies
NAWCWD, with industrial and academic partners, is developing next-generation energy solutions for the Warfighter in the areas of advanced energy storage and generation technologies to harvest the power of the sun and water, solar generation systems to support expeditionary and tactical operations, micro-grid technologies to increase installation and operational energy security, and technologies to convert waste streams into energy and power, as well as pioneering the cutting-edge fields of solar-powered and biofuel-powered UxS.

Geothermal Energy
Today, the Coso geothermal power plant is a world-class Navy resource, with total savings to NAWCWD exceeding $36 million. The Coso geothermal power plant produces enough power for 330,000+ homes. Scientists at China Lake were assigned the lead role for Navy geothermal efforts, even those not geographically limited to China Lake. As environmental concerns continue to shift toward "greener" power sources worldwide, geothermal technology will stay at the forefront to supply energy by using the earth's inner heat.

Other Energy Initiatives



Solar Farm at Santa Cruz Island

Santa Cruz Island, located 30 miles off the coast of Point Mugu, has three photovoltaic systems providing power to remote facilities. One of these is a 150-kilowatt battery system that provides power to radar and communication equipment. In addition, a second photovoltaic system provides power to pump water to the highest point on the island, which is located 8.5 miles from the water well, and a third project includes a 30-kilowatt portable photovoltaic and battery system.

Photovoltaic Carports and Other Solar Thermal Projects

New photovoltaic carports and other solar thermal projects save the Navy more than $1 million annually. These projects were sponsored by an award from the American Recovery and Reinvestment Act of 2009, with the intent of reducing the carbon footprint and energy consumption of the base. Very large carport-mounted solar photovoltaic structures were installed in three of the largest parking lots on base, including those at Michelson Laboratory (155 kilowatts), Armitage Field (248 kilowatts), and Range Headquarters (230 kilowatts). The solar systems supply power to the buildings and feed energy back into the power grid when there is excess electricity produced. All the solar photovoltaic projects at China Lake combined should generate approximately 1 megawatt of annual renewable energy.

Project for 750-Kilowatt Molten Carbonate Fuel Cell Demonstrator at Marine Corps Base (MCB) Camp Pendleton

Integral to the renewable energy strategy, NAWCWD's Renewable Energy Laboratory is often called upon by other DoD partners to provide expertise and consultation regarding energy technology RDT&E. As an example, the 750-kilowatt fuel cell demonstration at Camp Pendleton was spearheaded by NAWCWD's scientists and engineers. The system provides base load power and heat, with environmental and energy security benefits.

Proton Exchange Membrane Fuel Cell Project at China Lake

NAWCWD engineers have been demonstrating new ways to store energy for use at night. Instead of acid-based batteries, the system is built around a hydrogen fuel cell. Electricity generated during the day powers an electrolyzer to generate hydrogen fuel from water. When the sun is no longer generating electricity in the panels, the fuel cell kicks in to generate power from the stored hydrogen. Currently, the Renewable Energy Laboratory at China Lake is optimizing the system to increase efficiency and reduce costs.

“First and foremost, energy conservation extends tactical range of our forces while also preserving precious resources. Our goal, as a Navy, is to be an ‘early adopter’ of new technologies that enhance national security in an environmentally sustainable way.”

—Rear Admiral Philip Cullom
Director of the Chief of Naval Operations Energy
and Environmental Readiness Division

NAVAIR

Naval Air Warfare Center
Weapons Division
China Lake and Point Mugu
California

NAWCWD TS 10-102